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SCIENCE FOR FORESTERS:

OR

A PRACTICAL INTRODUCTION

TO

CHEMISTRY, GEOLOGY, VEGETABLE PHYSIOLOGY, AND BOTANY,

AS AIDS IN THE SELECTION OF SITES AND SOILS,

AND

THE PROFITABLE GROWTH OF TREES.

By A. J. BURROWS, F.L.S., F.S.I., &c.

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1884.

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PREFACE.

THE present little work comprises part of a scheme sketched out many year ago, and the object of which was to provide the young forester—who often has but little leisure for consulting larger works—with a manual for his guidance and assistance in every department of his labours. It was intended to include in a moderate-sized volume :—(1) *Science for Foresters ;* (2) *Practical Forestry* ; (3) *Timber Trees*, their sites, soils, uses, beauties, &c. ; (4) a *Forester's Calendar*. Materials for the completion of such a work were put together and require only revision and arrangement. Meanwhile the following pages are issued as one of the useful series of "Forestry Handbooks," with a hope that they may to some extent conduce to the more scientific and intelligent prosecution of labours which are of primary importance to landowners and to the nation at large.

A. J. BURROWS.

PLUCKLEY, KENT, *March*, 1884.

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SCIENCE FOR FORESTERS.

A KNOWLEDGE of the substances of which any plant or tree consists, and an intimate acquaintance with the properties of the soil in which it is to be placed, will enable the planter to determine at once whether in his selection of a site he is putting within the reach of that tree all the elements necessary to ensure its healthy growth; or it will enable him to modify his soil by cultivation and manuring so as to fit it for the requirements of the tree, so far as this can be brought about by artificial means. But in order to insure this result he must not only possess a knowledge of the elements of matter, but he must also understand the laws by which they act both singly and in combination with other bodies. Chemistry, by the dissection of bodies, finds out their constituent parts: this process is called *Analysis*, and by its aid we are enabled to separate the component parts of all substances, whether these be solid, liquid, or gaseous, into their elements. By the opposite process, which has been called *Synthesis*, we are enabled to reunite these elements in such proportions as to produce the original substances. All elements manifest certain dispositions to combine or reunite when separated, and this property is known as *Affinity*. While Physics explain the causes, it is the province of Chemistry to investigate the processes and record the results.

CHEMISTRY OF SOILS.

Some knowledge of the chemistry of soils is as essential to the forester as to the agriculturist; for while the latter can so far modify his rotation of crops and his supply of manures, natural or artificial, year after year, as to meet his requirements, the former cannot hereafter atone for errors of judgment except by an outlay which may prove utterly disproportionate to the results obtained. The farmer's crops derive their nourishment mainly from the surface soil, which cultivation may easily alter; but after the first stages of its growth the

timber tree is largely dependent upon the subsoil, and if this prove ungenial the fate of the tree is sealed.

The parts of plants and animals are divided into combustible and incombustible, or organic and inorganic. The incombustible parts are the ashes left after burning, the combustible or organic parts those which are driven off or apparently eliminated by fire; the former being taken up mainly by the roots of plants and the latter by the leaves. All animal and vegetable substances are organised, that is, they contain pores orderly arranged, and these pores are called organs. On the other hand, the mineral substances are inorganic. By burning a piece of wood, a bundle of straw, or a portion of soil in the open air, its bulk and weight are very considerably diminished. This diminution is owing to the loss of the organic part, which has been burnt away or reduced to its elements and set free by the action of the fire. In this process some kinds of wood leave only ½ per cent. of ashes by weight; grain of various kinds from 2 to 3 per cent., and straw about 5 per cent. The quantities of inorganic matter vary very considerably in different vegetable substances, thus: wheat-straw leaves about 112 lbs. per ton as ashes; oat-straw, 134 lbs.; the grain of wheat, 45 lbs. per ton, and of oats, 90 lbs; while oak wood produces from 4 to 5 lbs. Experiments tried upon the dried wood and leaves of other trees showed that the ashes left by willow wood was 4½ lbs. per 1,000, and by the leaves 82 lbs.; by the beech, 4 lbs. and 42 lbs.; by the birch, 3½ lbs. and 50 lbs.; and by the elm, 19 lbs. and 120 lbs. These experiments prove conclusively that a very large proportion of the mineral and saline matters taken up by the roots of trees are annually returned to the soil by the fall of leaves.

Chemistry proves that to obtain luxuriant growth at least eight substances must be present in the soil: what these are will appear in due time. Nor will the superabundance of any one element compensate for the absence of another, as certain plants require and take up only given quantities of their constituents; so that if ten times the required quantity be present it may nourish ten successive crops of the same kind, but at the same time it will not promote the growth of any one crop beyond a certain point. The exhaustion of any soil to which nothing is added in the form of manure will depend very much upon the comminution of its parts, as the more thoroughly this is effected the greater will be the supply of food placed within reach of the plants. It is necessary not only that the food be present in the soil, but that it exist in such a form as to make it available for use. Thus if 100 lbs. of potash and 50 lbs. of phosphoric acid are required to produce 10,000 lbs. of straw and 4,000 lbs. of wheat, these

substances must not only be present in the land in the above quantities, but they must also be in a sufficiently soluble state to render them available.

The substances known to the chemist are divided by him into *simple* and *compound : simple substances* contain but one ingredient, and are incapable of being resolved ; *compound substances* may be subdivided into their elements. Organic matter, whether derived from plants, animals, or soil, consists mainly of four elements, carbon, oxygen, hydrogen, and nitrogen, with which are generally associated small portions of sulphur and phosphorus. Everything existing in the earth, or upon and above its surface, is made up of one or more of sixty-three elementary bodies, fifteen of which are called non-metallic substances, and forty-eight metallic. Some of these exist as gases, some as fluids, and others as solids, and some are changeable in their forms : thus, water in its natural state exists as a fluid ; subjected to a high temperature it becomes steam or vapour, and under the influence of frost it becomes ice. Most organic substances are easily decomposed by high temperature, by long exposure to the air, and by decay or putrefaction. The pores in wood and the small vessels or fibres in animal substances, which are the organs of life, are thus rapidly destroyed. Heat also reduces compound substances to their elements : thus, wood burnt in a retort yields tar, water, pyroligneous acid, and charcoal ; while lead ore gives off under heat a portion of sulphur, leaving only pure lead ; the charcoal and lead being pure or simple bodies, and the wood and lead ore compound ones.

NON-METALLIC SUBSTANCES.

Out of the fifteen non-metallic substances found in nature there are eight which are important in their relations to vegetation. These are carbon, oxygen, hydrogen, nitrogen, sulphur, phosphorus, chlorine, and silicon. In writing of these substances and their combinations, certain signs, consisting chiefly of the initial letters of the names, and certain numbers, which are called equivalents, are used by the chemist. These signs and their numbers and powers will be further explained when we come to treat of compounds.

Carbon (C) is familiar to us as a solid body in the form of charcoal, coke, coal, black-lead or graphite, and the diamond. By taking equal portions of charcoal, black-lead, and diamond, and burning them, we obtain equal portions or weights of carbonic acid gas. Carbon forms a part of all organised, or animal and vegetable matters ; and when these are burnt the carbon passes off as carbonic acid gas, leaving a small portion of inorganic matter in the form of ashes. Next to the diamond, wood charcoal is the purest form of carbon, the wood

being burnt in closely covered heaps or in retorts. It contains a very small admixture of earthy and saline matters. Carbon composes from 40 to 50 per cent. of all vegetable food in a dry state. In the form of plumbago or black-lead it is two and a half times heavier than water; as diamond, three and a half times heavier. As charcoal it absorbs vapours and gaseous substances from the atmosphere, takes up decayed animal matters and colouring from water, absorbs disagreeable odours, and takes saline substances from water. As a solid substance it is quite insoluble in water, and it must be combined with oxygen, in which state it forms carbonic acid gas, before it can be taken up by plants. In this state it enters through the pores of the leaves and of the rootlets, both in a liquid and a gaseous form. That it comes largely from the atmosphere is shown by the fact that land lying long in pasture becomes richer in vegetable matters year after year. The same remark applies to land under timber of various kinds, where the accumulations are aided by the decay of the foliage. If the crops took in carbon from the soil alone they would rapidly exhaust it instead of rendering the land richer in this substance, for by constant cultivation and no manure land is soon robbed of most of its organic matter. That this does not result from the exposure alone is proved by the fact that a three years' bare fallow will not, even with constant cultivation, take so much out of the land as a one year's fallow followed by a corn crop.

Probably the whole of the carbon found in plants was originally derived from the atmosphere. As vegetable matters decay, part of their substance passes off as gas into the atmosphere, and part incorporates itself with the soil. From the rapid decay of such matters the soil in the warmer regions of the earth receives less of their substance. The accumulation is much greater in temperate climates, and it attains its maximum between the parallels of forty and forty-five degrees Here are found peat-bogs—accumulations of vegetable matters on a large scale.

Oxygen (O) exists in the atmosphere as a gas, invisible, tasteless, and colourless. It combines with nitrogen in the proportion of one to four, or four parts of nitrogen to one of oxygen. In combination with the other elementary substances it produces heat and light. It exists in all rocks, soils, and mineral substances, constituting more than half the weight of the entire globe. Animals live by its agency, and as they inhale it internal heat is produced. By its action it also purifies the blood. A light placed in it burns very rapidly and with great brilliancy, and is consequently soon burnt out. Animals placed in it breathe quickly and are soon exhausted. It is one-ninth heavier than common air. It forms one-fifth of the bulk of the air we breathe, being the principal

supporter of animal life and of combustion. Without it plants would not grow, and its withdrawal from the atmosphere would cause the destruction of all living beings, animal as well as vegetable. It forms about 21 per cent. of the bulk of the atmosphere, and 9 lbs. of water contain 8 lbs. of oxygen. Next to carbon it is the most abundant constituent of plants, which it enters in combination with nitrogen as atmospheric air. As plants take up more of it than they require, the organs in the leaves decompose it and separate it from the carbonic acid gas, thus purifying the atmosphere by the removal of the latter and the return of the oxygen. Animals by breathing absorb oxygen and give out carbonic acid. The carbonic acid gas taken in by plants is decomposed only in the sunlight, so that plants give out no oxygen during the night, but, on the contrary, absorb small quantities. As about eight-ninths of the water absorbed by plants consists of oxygen, and the atmosphere also contains 21 per cent. of it, while carbonic acid gas is composed of 72 per cent. of it by weight, it is easily seen how plants obtain the large quantities of oxygen they require.

Hydrogen (H) is the lightest of all known substances, and on this account it is employed in filling balloons. It seldom or never exists in a free state in nature, but is found in water and other substances in a state of combination. This gas is also colourless, tasteless, and invisible. It exists in all acids, and is 14½ times lighter than common air. Combined with carbon it forms fire-damp, a dangerous substance found in coal gas. Hydrogen puts out the light, but immediately takes fire itself. It forms one-ninth the weight of water. Not being found free it cannot be taken up by plants until it is combined with oxygen in the form of water, or with nitrogen, as in the ammonia of animal manures. Water being a combination of hydrogen and oxygen, everywhere present in the soil in the form of a liquid, and in the atmosphere in the form of vapour, both of which plants in a growing state are continually decomposing, they obtain their supplies of hydrogen from this process. And in highly manured soils we find an abundance of carburetted hydrogen thrown off by the decay of vegetable matters.

Nitrogen (N) is also without colour and taste, and invisible, but unlike hydrogen it exists in the air in a free state. It is also found in ammonia, or spirits of hartshorn, in nitre, or saltpetre, and in nitric acid. It neither burns itself nor is it a supporter of combustion or of animal life, for animals placed in it die, not from the nitrogen itself but because they are deprived of oxygen. It is nearly as heavy as common air, of which it forms four-fifths of the bulk, or 79 per cent. Compared with common air, it is in weight as 97¼ to 100. It forms

from 1 to 2 per cent. of the bulk of coal. When in contact with flame it simply puts out the light. Though found only in small quantities in plants, its presence is very essential, as it forms the principal ingredient in the gluten, and by its influence the colour is produced in the leaves and flowers. With an average crop of hay of two tons, each acre of land will send about 60 lbs. of nitrogen into the farmyard. This substance is not found in any of the solid rocks, though it is present in coal, which is of vegetable origin. It makes its way into the roots of plants in solution, 100 cubic inches of rain water carrying into the soil about $2\frac{2}{3}$ inches of nitrogen gas.

In crops of corn, hay, roots, and seeds which have been dried by artificial means, carbon will be found to form one-half the weight, oxygen one-third, hydrogen 5 per cent., and nitrogen $2\frac{1}{2}$ per cent., while sulphur exists in proportions varying from 1 to 5 per cent., and phosphorus constitutes about the one-thousandth part.

Sulphur (S) is a solid substance of a light yellow colour, and possessed of a slight odour. When brought in contact with fire it burns with a blue flame, its fumes being oppressive and almost suffocating. It exists as a fine yellow powder, and is made up into sticks or rolls. Its union with the oxygen of the air in burning forms an oxide of sulphur. It is found free in volcanic districts, such as the Island of Sicily. Combined with metals it forms the sulphides, such as sulphate of lead, etc.; and when combined with oxygen and hydrogen it forms sulphuric acid, commonly called oil of vitriol. When mixed with hydrogen it forms a sulphuretted hydrogen, which is the principal medicinal ingredient in the Harrogate waters. It is nearly twice as heavy as water, its gravity being 1·98. It will not dissolve in water, but it melts at 234° Fahr. When plants are burnt, the sulphur escapes in part as a sulphurous acid, so that the ash furnishes no certain indication of the quantity of sulphur contained in the living plant. The proportions of sulphur vary greatly in different plants, but straw and leaves contain more of this substance than the grain and the timber.

Phosphorus (P) does not exist in a free state, but is found chiefly in the bones of animals, where it exists in combination with oxygen. There are two kinds of phosphorus—the red and the yellow, and these exhibit very different properties. Rub a piece of yellow phosphorus, and it takes fire, and when exposed to the air it smokes, and is luminous in the dark. In burning it emits a great deal of smoke. It is largely employed in the manufacture of lucifer matches. Striking an ordinary match removes the coating or varnish from its tip, and the phosphorus takes fire. In those matches which strike only upon the

box, the paper of the box is covered with some powdered red or non-inflammable phosphorus, a little of which sticking to the end of the match combines with the mixture thereon and causes a flame. Phosphorus is a waxy kind of substance, not unlike beeswax, and is found in igneous rocks, in granite, trap, basalt, and in small quantities in most minerals. It melts at 108°, and in hot weather it will ignite spontaneously; it should therefore be kept in cold water. Though never found free naturally, it is mixed with carbon, oxygen, hydrogen, and nitrogen, in blood, milk, flesh, the substance of brain, and in all cultivated plants. Its specific gravity is 1·77.

Chlorine (Cl) is a yellowish gas, very strong-smelling and poisonous, not found free in nature. It gives its peculiar smell to chloride of lime, and forms more than half the substance by weight of common salt. Combined with metals it forms the chlorides. In possesses a strong bleaching power, and is a principal ingredient in bleaching powders of various kinds. It very rapidly takes the colour out of cotton and linen cloths put into it.

Silicon (Si), or its oxide, known as silica, is the common quartz or rock crystal of the geologist. Flint, sand, and sandstone consist very largely of silica. In combination with metals it forms silicates, which act a very important part in the economy of vegetation. Silicon is a dark brown powder, and when heated in the air it combines with oxygen and forms silica, which consists of 48 of silicon with 52 of oxygen. It is not met with free. Clay is one of the most important of the silicates; and the articles made from clay, such as bricks, draining pipes, pottery, terra-cotta, and china, are all silicates; so is glass, which is produced by fusing white sand, lime, and soda for the plate glass, and sand with the oxide of lead and potash for the common flint glass.

METALLIC SUBSTANCES.

Having already described the most common of the non-metallic substances, we now proceed to give some account of the metallic elements which will hereafter be found to come within the range of those with whose presence in the soil the forester has to deal. These are iron, aluminium, calcium, magnesium, sodium, and potassium.

Iron (Fe, from the first letters of the Latin name *ferrum*) is found mainly as an earthy ore, from which the pure metal is obtained by means of fire. It exists in nature in a great variety of forms, combined with oxygen, with sulphur, and with carbonic acid. One of its most useful ores is the red

hæmatite, in which it is combined with oxygen, which can be got rid of by burning it with charcoal. The iron thus obtained is hammered out into bar iron of various kinds, or flattened into plates between rollers, and is afterwards called wrought iron, which possesses the valuable property that it can while red-hot be welded in such a manner that no ordinary force will separate it. By putting iron ore, coal, and limestone together into a blast-furnace, and thus smelting the iron by means of the strong blast, it can afterwards be run into moulds of any size and shape. This is cast iron, which is so brittle that it will not stand hammering. It contains a considerable quantity of carbon, which it gets from the coal. By puddling, the carbon is driven off or consumed, and wrought iron is produced.

As an oxide iron is present in the ashes of all plants. It is seen in one of two forms,—the protoxide, which is black, or the peroxide, which is red. The former becomes red by exposure. It leaves an ochrey deposit in water, and this deposit is seen adhering to the leaves of plants growing upon the banks and in the beds of small streams impregnated with iron. Soils containing sulphate of iron are barren until they are dressed with lime, which enters into combination with the sulphuric acid and produces gypsum.

Aluminium (Al) is a metal which can be got from common clay; when subjected to great heat in the air it forms an oxide, which is called alumina, and is insoluble. One of its best known compounds is alum, which is a mixture of alumina, potassa, and sulphuric acid. The purest clay consists of about two parts of alumina mixed with three of silica. The process of getting the aluminium from the clay is a very costly one, else the metal would be much more extensively used. Metallic aluminium has the colour of iron, and when heated it burns and produces its oxide, alumina. From pure felspar the white potter's clay is obtained; but when there is much oxide of iron present the clay is either yellow, red, or brown. It combines with oxygen to form alumina. It is found crystallized, as in rubies and sapphires, being white, powdery, and tasteless.

Calcium (Ca) is a metal which exists very plentifully in compounds though it is with difficulty obtained in a pure state. It exists in quicklime, which is a calcium oxide; in coral, limestone, marble, and chalk, all of which are carbonates of calcium. Gypsum is a sulphate of calcium, and bone earth is its phosphate.

Magnesium(Mg) is a substance very abun dant in sea water and in that of some springs, and it exists in some kinds of limestone. Its oxide is magnesia. It is soft and silvery white in colour, and is often made into wire and ribbon.

It is burnt as a light when great brilliancy is required, and it is also used in fireworks and for signals. It retains its brightness in a dry atmosphere. Epsom salts are only a magnesium sulphate. It is present in all fertile soils, but chiefly in those formed by the disintegration of the magnesian limestone. These soils are generally cold, as they absorb much moisture. The Epsom salts, which are a sulphate of magnesia, are formed by the decomposition of the rocks called Dolomite. Magnesia is found in small quantities in the ashes of plants, particularly in those of the horse-chestnut and of oak bark. In the soil it is found in combination with oxygen.

Sodium (Na) is a metal which cannot be kept exposed to the air, on account of its rapid oxidization. It can, however, be kept covered with rock-oil. When brought in contact with water it sets free the hydrogen and immediately combines with the oxygen. If a small piece of this metal is thrown upon water it swims on the surface, liberating the hydrogen, and then combining with the oxygen to form soda. It is the metal found in sea-salt and rock-salt, in Glauber's salts, and in washing soda. Burnt seaweed and the ashes of all seaside plants yield soda. An application of it is found to be very beneficial to sea-kale and asparagus. Rock salt is found in great abundance in Cheshire.

Potassium (K) is the metal of the alkali potash, and of potash salts. If a small piece is thrown on water it at once combines with the oxygen, and the hydrogen takes fire. Potash salts are abundant in the ashes of plants. Nitre or saltpetre is a potash salt in common use. Potassium may be formed in an iron bottle or a retort by using some dry carbonate of potash with charcoal. The metal thus obtained is very soft, easily melted, and silvery in colour. When in contact with water it burns with a very beautiful purple flame. It is much lighter than water. Its oxide, potash, is abundant in the felspar found mixed with granite. The rocks are disintegrated by the action of the atmosphere, and thus the potash is rendered soluble and at once available for plants.

The above are the principal elementary bodies which in greater or less degrees enter into the composition of plants. Being present in nature they are brought together by the power of *attraction*, which is either magnetic, electric, the attraction of gravitation, or of cohesion, or capillary attraction. By magnetic attraction iron is drawn to the poles of a magnet. By electric attraction either a stick of sealing-wax or a glass tube may, by rubbing with a dry silk pocket-handkerchief, be made to attract small pieces of paper. By gravitation bodies fall to the ground, and the planets circle round the sun. By cohesion the two halves of a cut apple or two balls of lead will stick together when

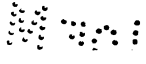
rubbed against each other. Capillary attraction is exemplified by the way in which water rises through the pores of a lump of sugar. Chemical attraction is known by the name of *affinity*, and it differs from all other kinds by producing a marked change in the substances brought together. Indeed, all the chemical changes are the results of chemical attraction or affinity, acting either by combination or by producing decomposition. Notwithstanding the unceasing changes which are continually going on around us, not a particle of matter is destroyed or lost, but only changed in form.

All combinations of bodies are governed by certain laws, in obedience to which they unite in definite proportions. The numbers which represent these proportions are called the atomic weights of the substances, and in these numbers or their multiples alone will such bodies combine: thus, 56 parts of iron and 32 parts of sulphur by weight combine to form sulphide of iron; or the 56 parts of iron will combine with 16 parts of oxygen by weight to form an oxide of iron. These are the lowest proportional numbers in which the above substances will combine: and the sum of the weight of any chemical compound is equal to the sum of the weights of its elements. Thus, 16 parts by weight of oxygen and two parts by weight of hydrogen will produce by weight 18 parts of water.

The combining weights of the elements which have already been described in this work are as under:—

Non-Metallic.			*Meta'lic.*		
Carbon	C	12	Iron	Fe	56
Oxygen	O	16	Aluminium	Al	27
Hydrogen	H	1	Calcium	Ca	40
Nitrogen	N	14	Magnesium	Mg	24
Sulphur	S	32	Sodium	Na	23
Phosphorus	P	31	Potassium	K	39
Chlorine	Cl	35			
Silicon	Si	28			

It has already been stated that in forming compounds the elements combine in definite proportions, which are either their simple equivalents or multiples of these. This has been exemplified in the case of water, which consists of 2 of hydrogen and 16 of oxygen; or to express this in chemical language, water $= H_2O$, which again is $2 + 16 = 18$. In the same way carbonic acid is expressed by CO_2, or 44, the combining weight of carbon being 12 and of oxygen 16.



Ammonia is $NH_3 = 14 + 3 = 17$. Lime is $CaO = 40 + 16 = 56$. Hydrochloric acid is $HA = 1 + 35$, or 36.

From combinations of the simple elements are obtained the acids and alkalies. An *Acid* is a substance that will turn red a blue litmus solution. It is very sour and corrosive. Acids are present in considerable quantities in many plants and in unripe fruits of all kinds, such as the grape, the apple, and the orange. If a few drops of sulphuric acid be added to a glass of water it will taste sour. If a little of the liquor in which red cabbage has been boiled be put into a glass of water, and a little of the diluted sulphuric acid be also added, the water which was blue before will now be changed to a red colour.

An *Alkali* turns red litmus solution blue and neutralizes an acid. Potash soda, and ammonia are the most important alkalies. Lime and magnesia are alkaline earths. The alkaline taste is that of the common soda and pearlash. If a solution of ammonia be added drop by drop to the red liquor obtained as above, the colour will gradually change to a greenish blue, and it will afterwards be found to have lost its sour taste.

When a substance can be dissolved in water it is said to be soluble, and the mixture obtained is called a solution. Sugar and sulphuric acid will combine with water, but oil and ether will not so combine with it. If a spoonful of lime be put into a bottle of pure water, and it be well shaken up and corked, and then poured off after the unslaked lime has settled, a solution of lime water will be obtained. Breathe into this by means of a small glass tube, and carbonate of lime is formed by the oxygen which proceeds from the lungs, as is shown by the milky appearance of the water.

Nitric Acid (NO_5) will afford us a good example of an acid and its effects. This is a liquid obtained by heating in a retort a portion of common nitre or saltpetre which has been covered over with oil of vitriol. In hot countries it abounds in combinations known as nitrates, such as soda, lime, and magnesia, which attract moisture and then liquefy. It combines with potash to form saltpetre, and with soda to form nitrate of soda. Put half an ounce of powdered nitre in a retort, and pour on it the same weight of sulphuric acid, place a lamp under the retort, and a flask which should be kept cool by a basin of water; a yellow liquid will appear in the flask which will be nitric acid, sour and corrosive in the highest degree. Nitric acid is supposed to be formed in the atmosphere during a thunderstorm, and to be washed down to the earth by the rains.

Ammonia (NH_3) is a gaseous substance which is given off in considerable quantities by putrefying animal matter, when it rises into the atmosphere, to be again brought down by rains. It abounds in farmyard manure and in guano, and is also found in the juices of the birch and maple, and in beetroot in combination with sugar. The application of a little lime will show its presence in fungi and in the tobacco plant as well as in elder flowers. We also recognise it in the odour of many plants. Though it is colourless it may easily be detected by its powerful smell and strong taste, as in hartshorn and common smelling salts. It will put out a light, but not burn of itself. If applied in strength it will kill animals and vegetables, and rapidly reduce their texture. Ammonia is taken up in large quantities by charcoal as well as by burnt clay and dried earth, and by all porous soils. Ammoniacal gas mixed with carbonic acid forms carbonate of ammonia. It is about three-fifths the weight of common air. When it comes in contact with the vapour of vinegar it forms a solid. Its smell is pungent and irritating. When horn, hair, feathers, and bones are burnt, their nitrogen combines with hydrogen to form ammonia. It is a very volatile substance, and by means of heat it may be driven out of most compounds which contain it. In fermenting manures, and in liquid manure tanks and stables, it may be fixed by the use of gypsum. The loss of ammonia from the fermenting dunghill, the tank, the stable, from coking ovens and ironworks is incalculable. As manure decays in hot weather and in an exposed state, a considerable portion of its ammonia is converted into nitric acid, and afterwards washed out by the rains.

Carbonic Acid (CO_2) is an invisible gas which is slightly odorous. It is more than 1½ times heavier than common air. It extinguishes fire, and is poisonous to animals. It forms nearly one-half the weight of calcareous rocks, or about 22 in 50 lbs. 22 lbs. of carbonic acid gas contain 6 lbs. of charcoal and 16 lbs. of oxygen. It forms a very considerable part of the food of animals. Invert a jar or a bottle over the flame of a burning candle, the carbonic acid which collects in it will descend until it puts out the light. Take a lump of chalk and pour an acid upon it, bubbles will be given off. Burn the chalk in the fire and then add an acid, and no effervescence will take place, showing that the carbonic acid has been driven off by the fire. This gas is given off plentifully by the lungs of animals in breathing, and taken in largely by plants during the day. The plants then assimilate the carbon and liberate the oxygen, thus purifying the air.

The atmosphere which surrounds our globe is about forty-five miles high;

and Liebig tells us that if all the carbonic acid and ammonia which are scattered throughout it could be collected into separate strata at the level of the sea, and at the same density as the atmosphere, carbonic acid would be little more than eight feet high, and ammonia not more than one quarter of an inch. We are told upon the authority of Professor Johnson, that upon lands of average fertility from one-third to four-fifths of the entire amount of carbon contained in the crop is obtained from the air; and to catch the small amount of carbonic acid the tree hangs out thousands of square feet of leaf surface, in perpetual motion through an ever-moving air, and thus by the conjoined labours of millions of pores the substance of whole forests of solid wood is slowly extracted from the fleeting winds. Upon a square inch of the surface of a common lilac leaf 120,000 pores have been counted, and upon an oak tree 7,000,000 of leaves.

Sulphuric Acid (SO_3) is obtained by burning sulphur in a furnace where at the same time nitric acid is being formed by the decomposition of nitrate of soda. It is called also oil of vitriol, and is a heavy oily liquid used in making soap, alkali, and also used in dyeing, printing, and bleaching. With metals it forms sulphates, as sodium sulphate, etc. In its most concentrated state it is a solid, highly deliquescent, crystallizing in long and silky-looking needles. The specific gravity of what is commonly sold as oil of vitriol is 1·85. Its action upon organised matters is highly corrosive. It chars wood left in it for a few minutes. It possesses a great affinity for the elements of water, which it draws from the organic matter with which it comes in contact, leaving the charred carbon behind.

Besides the substances already described, there are a few others whose presence in soils of various kinds renders it necessary that some description of them be given before we come to treat of the composition of soils.

Lime (CaO) is an oxide of calcium, obtained by burning chalk or limestone in a kiln. As quicklime, caustic or hot lime, it consists of oxygen gas combined with the metal calcium. In its fresh burned state it is strongly caustic or alkaline. When sprinkled with water it swells, cracks, and finally is reduced to a powder; this is hydrate of lime. By exposure to the atmosphere it absorbs carbonic acid gas, and becomes reconverted into carbonate of lime. It is indispensable to the growth of plants, and is abundant in their ashes. It exists in many other forms, such as sulphate of lime, phosphate of lime, silicate of lime, and nitrate of lime. The most important of these are sulphate of lime ($CaSO_4$), or gypsum, and phosphate of lime ($CaH_4P_2O_8$).

Oxide of Iron (Fe_2O_3), or ferric oxide, produces the red and brown tints of clays and sands. The blue colour of rocks and clays is also due to the oxide of iron, and these generally become red after exposure to the weather. The rust which forms on bright iron upon exposure to the air is this oxide. By exposure the injurious sulphate of iron contained in soils is converted into the harmless oxide; hence the necessity for thoroughly working and pulverizing such soils.

Humus is the substance which imparts its dark colour to garden mould. It consists of vegetable matters in different stages of decay. It possesses many of the properties of charcoal, particularly those of absorbing and retaining gases. It also supplies carbonic acid gas to the soil, and in its dry state it collects ammonia from the atmosphere.

Phosphoric Acid (PO_5) may be obtained by burning a piece of phosphorus on a stoneware plate, and collecting the dense white fumes in a bell glass placed over the plate. The fumes condense in soft, white, and crystallized flakes which resemble snow in appearance. It is an important constituent of the plants cultivated as food for man, and is found in all fertile soils. It occurs in the limestone and other stratified rocks, and also in the igneous rocks, granite, trap, and those of a basaltic kind. The bones of animals contain phosphoric acid in combination with lime, and it is from this source that it is generally obtained.

COMPOSITION OF THE ATMOSPHERE AND OF SOILS.

It has been already stated that the organic or combustible parts of plants are derived mainly from the atmosphere, and the inorganic or mineral parts from the soil. We have, therefore, now to consider the composition and the action of these two important auxiliaries to plant growth, and the way in which, by the assistance of moisture, light, and heat, they build up the framework of all vegetable substances, from the smallest lichen to the stateliest forest tree.

The **Atmosphere** is composed of nearly four measures of nitrogen with one of oxygen. It is the medium through which heat, light, and moisture are conveyed to plants and animals, and to the soil itself; while at the same time it furnishes the laboratory in which both meteorological and electrical phenomena are perfected. The exact proportions of the atmosphere are 21 of oxygen to 79 of nitrogen — carbonic acid gas forming about $\frac{4}{2500}$ part of the entire bulk. The air is generally diffused, so that it insinuates itself into the leaves of trees,

through their pores, and into the roots, trunks, and branches, in combination with the food which enters through the spongioles. In drained or fairly dry land the heat of the sun expands the contained gases, the shower afterwards penetrates the soil and removes them, and at the same time fresh supplies are imparted.

Air may be described as an elastic, colourless fluid, which is discernible by the senses only when it is in motion. At the freezing-point (32° Fahr.) it is 769 times lighter than water. The atmosphere extends to a height of from 45 to 50 miles above the surface of the earth, and it exerts a pressure of nearly 15 lbs. upon every square inch of surface, which is equal to a column of water 34 feet high, or a column of mercury of 30 in. Air is highly necessary to every part of the plant, as it conveys the oxygen of the atmosphere, combined with carbonic acid, to the seed-vessels; and without its aid no wood is formed and no seed ripened. Large quantities of carbonic acid gas are given off by the lungs of animals, and set free by the burning of fuel. Much of this is at once seized upon and appropriated by vegetation. The remainder rises into the atmosphere, and is afterwards conveyed by the polar currents to the tropics, where it contributes to the luxuriant growth of plants. Here the oxygen is liberated and carried back by the upper currents of air, and thus the equilibrium is restored.

Being subject to expansion by heat and contraction by cold, the warmer or lighter volumes of air ascend, and the colder and denser air rushes in from all sides to supply its place. This gives rise to currents of air, or winds. These winds are of great use in dispersing clouds resting over the earth's surface, and in scattering the seeds of plants, many of which are furnished with volant appendages to enable them to travel to a distance, or with capsules more or less elastic, which burst and scatter the seeds around. The winds also assist in purifying the atmosphere from noxious vapours and effluvia of all kinds; and on account of their blowing at certain seasons of the year for a long time in one direction, and therefore being of the greatest service in propelling vessels, these are called *trade winds*. They are caused mainly by the ascending columns of hot air in the tropical regions, and the rushing in of air from regions lying north and south of these.

The air upon the sea-shore and near large inland lakes contains the least carbonic acid. There is still less at sea; less present in the daytime than at night; and less over moist than over very dry soils. The ammonia and its various compounds present are given off by decaying animal and vegetable substances. Were it not for the atmosphere, light would produce none of those

brilliant colours which adorn vegetation, and sound could not travel, dependent as it is upon the undulations of the air.

Water in its various forms is familiar to us as either a liquid, a solid, or a vapour or gas. When its temperature is reduced below 32° at the sea-level it becomes frozen; when raised above 212° at the same level, or above 189° at the top of Mont Blanc, a height of about three miles, it boils, and escapes as vapour or steam, which is an invisible gas raised by heat to 1,700 times its former volume, and in this state nearly two-fifths lighter than common air.

By passing a current of electricity through water it can easily be split up into its elements, or decomposed, its component parts being two of oxygen to one of hydrogen by volume; or, as hydrogen is so much lighter than oxygen, this gives sixteen parts of oxygen to two of hydrogen by weight.

Water is either fresh or salt. Salt water may be rendered fresh by boiling it, and then collecting and condensing the steam as it evaporates. This distilled water will be found perfectly free from saline matters. Salt cannot always be detected in water by the taste. But if it be present, three or four drops of silver nitrate put into a tumbler of it will immediately produce a floating, misty, or white cloud. The rain water from the sky is the purest, as this is raised from the surface of the earth by evaporation, and after floating in the atmosphere is again brought down by condensation. Even the very clearest spring water will leave some little residuum or sediment when boiled off.

When the water contains gypsum or sulphate of lime in a state of solution it is hard; and a very small portion of this substance dropped into a bottle of the purest rain-water, and well shaken up, will produce hardness. Boiling such water will not soften it, though water which is hard from the presence of chalk may be rendered soft by boiling, as the carbonic acid is thus driven off, and the lime is precipitated as a white powder.

Water acts upon the soil by contraction and expansion. The bulk of a given quantity of water is first lessened by cold and then expanded by frost. When a thaw comes the soil expands, and the water at first shrinks. This causes a crumbling of the outer layers of soil which thaw first, and which, from being separated from the inner mass by crystals of ice, fall off.

Snow protects the soil, and more particularly the crop, from the disastrous effects of sudden changes of weather. It also checks the escape of heat from the soil; and thus it is that both wheat and rye come out fresh and green from beneath a layer of snow. The colour may also be due to some extent to the

presence of ammonia, which is contained in snow. Professor Johnston discovered traces of it in snow falling near Durham, and at the same time he ascertained that the lower layers, or what had first descended through the atmosphere, contained more ammonia than the upper ones. Its presence in snow may be shown by melting a portion, taking four pints of the water, adding two drops of sulphuric acid, evaporating the water, and then adding some quicklime, when in the residuum may be traced both sulphate of ammonia and gypsum.

Pure water is perfectly free from taste, smell, and colour, and is therefore transparent. Water forms more than one-half the weight of all fresh gathered vegetables. When boiled under exposure to the air it increases by about one-thirty-sixth of its former bulk.

The quantity of moisture contained in the atmosphere depends very much upon the season, the climate, the latitude, and also the altitude. It is generally the least in the middle of winter and most during the heat of summer. The effect of a superabundance of water in the soil is that the food of plants becomes too much diluted, and the evaporation of the superfluous water keeps the surface cold, and in this way retards their growth. Moisture requires to be accompanied by both heat and air to render it beneficial to plants, for without these it only encourages decay, as in the case of seeds which do not germinate. Cutting off the supplies of air from the roots of plants encourages the growth of leaves at the expense of seeds or fruit, while too little moisture checks the growth of both leaves and fruit: when leaves are suddenly deprived of moisture they fade and fall away.

Heat in moderation quickens and intensifies the action of the organs of vegetation; in excess it consumes the substance or reduces it to its elements. If we burn a wax candle in a clean narrow-necked glass bottle it soon goes out. If we then pour some clear lime water in the bottle it becomes cloudy, and this cloudy appearance is due to the presence of chalk, or lime and carbonic acid gas. The carbonic acid is the produce of the carbon or charcoal of the burnt candle, which remains behind after certain portions have passed away as smoke or soot. Some water is also given off by the burning candle, as may be seen by inverting a tumbler over it, when drops will appear upon the inside of the glass. A whole day's fire, especially when wood is consumed, leaves but a small quantity of ashes, the bulk of the fuel having escaped as soot, as carbonic acid gas, and water.

One of the principal effects of heat is to cause EXPANSION. A bar of iron or

brass occupies more space in a heated than in a cold state, though the weight remains unaltered. Heat a pint of water or beer, and the pint measure will no longer hold it. Fill a bladder two-thirds full of air and hold it before the fire, and the air expands so as to entirely fill it: remove it, and it soon returns to its former condition. The thermometer is constructed upon the principle of the expansion of fluids by heat. Two points of temperature are fixed upon as measures of heat,—that of melting ice, or 32 degrees, which is also called the freezing point, because water begins to freeze and ice to melt by starting upwards or downwards from the same degree of temperature, and that of boiling water, or 212 degrees.

Heat possesses the property of penetrating different substances, and even of passing through them to other substances with which they are in contact. This principle is the conduction of heat. Place an iron rod in the fire, and as one end becomes heated to redness the other gets too hot to handle. Substitute a glass rod, and the one end will melt before the other attains any considerable heat. One is a good and the other a bad conductor of heat.

When water is rapidly evaporated from an exposed surface intense cold is produced, as the heat is carried away in a latent or concealed state by the moisture which escapes. Wrap a wet napkin round a bottle of wine and place it in the direct rays of the sun: as the cloth dries the wine becomes cooled. In the same way wet land is kept cold by the surface evaporation caused by the rays of the sun, on account of the escape of the latent heat. Consequently such rays cannot warm the land, as their whole force is expended in evaporating moisture. It has been calculated that the work expended in doing this upon very wet lands is equal to an expenditure of from 200 to 300 tons of coal per acre. When the water is removed by under-drainage no such waste of power takes place, and consequently the sun's heat immediately acts upon the seed to produce germination, upon the stem to promote growth, and upon the produce to impart quality and flavour.

Chemical union produces heat. Pour cold water upon quicklime, and both get hot, the water hissing and partly escaping as steam. The hot powder which remains is the result of a chemical combination, and this produces slaked lime, or hydrate of lime. Heat is an important agent in producing the ascent of the sap, and the expansion and development of the buds and leaves. Frost acts as a check to both. Heat, however, requires the presence of moisture, otherwise it proves injurious. Cold hinders the development of the leaves, the flowers, and the fruit, and lessens the flavour of the latter. The

secretions of plants are also diminished by cold; thus oil is derived both from the walnut and the beech in the south of Europe, but not in Britain. Mulberry leaves, also, afford less caoutchouc here than in France and Italy.

The source of both heat and light is the sun. A sunbeam consists of three distinct parts, one ray producing light, another heat, and a third, called *actinism*, different chemical phenomena. These rays are very differently refracted in passing through a prism, and the image of the sun received upon a screen shows separately the rays of light, of heat, and the chemical rays.

When two bodies possessed of different degrees of heat are brought in contact with each other the warmer body continues to give out its heat until the temperature of the two is equal. Heat may be described as a positive and cold a negative quality.

Light.—Though seeds will germinate without light, they cannot further develop without its aid, as the decomposition of the carbonic acid is checked. Light is also essential to the development of colours, particularly of those containing any blue. By inhaling carbonic acid gas, plants take up the light and heat of the sun, and thus form substances which will afterwards burn and give back precisely the same amounts of both light and heat.

Light is the principal cause of perspiration in plants, as by its agency the carbonic acid in the cells is decomposed. Where light is excluded, colour is wanting, and there is neither strength of tissue in the wood nor natural flavour in the fruit. It is mainly owing to the absence of light that closely crowded crops, and those growing under the shade of hedgerow timber and wide-spreading hedgerows, are so unproductive. Though the action of light upon plants is mainly through their leaves, it also acts in a less degree through the vessels contained in the bark. It has been proved to be subject to many of the same laws which influence other material bodies—attraction, repulsion, and chemical affinity; but its gravity seems still to remain a problem for solution. It moves only in straight lines, it rebounds from reflecting surfaces, and it passes into chemical union with acids and plants.

The velocity of light is so great that it passes from the sun to the earth, a distance of 95,000,000 of miles, in about 7½ minutes, which is equal to 200,000 miles per second, or a million of miles in five seconds. At this rate the light of the moon reaches our earth in 1¼ second.

Though the light of the sun is mainly white, every luminous body discharges light of its own colour: thus, we get a red light from a red rose, and green light from its leaves. Red rays are propelled with greater force than others, or, in

other words, they are the least refrangible. From this cause it arises that when the sun is near the horizon, and the rays have consequently to pass through a denser tract of air, the greater momentum of the red enables them to reach the eye of the observer, and to produce that brilliant hue which gilds all nature at sunset, from the lowly shrubs upon the lawn to the cloud masses in the sky.

By causing the rays of light to pass through a triangular piece of glass, called a prism, their usual white appearance becomes changed into seven colours, all of which shade or disappear in each other. These are red, orange, yellow, green, blue, indigo, and violet. This principle of refraction is the same as that which produces the rainbow, and the same effect may sometimes be seen in the mist or spray of a large waterfall, and in the volume of partially condensed steam escaping from a boiler.

Composition of the Soil.—Soil is before all things the most important consideration with the forester, as upon the adaptability of this to the requirements of his trees their success ultimately depends.

Soils consist of earthy and rocky matters in various stages of pulverization and decomposition, and these are produced by the crumbling down of rocks, a result of natural agencies. The soils differ very considerably in colour, according to the rocks from which they derive their origin; in texture, being more or less pulverized; in composition, and in depth. Sometimes a soil is so shallow that upon digging a hole only a few inches deep, we either penetrate the *subsoil* or come upon the rock formation on which the surface soil rests, and from which it is formed. The composition of this subsoil is to the timber grower a consideration of primary importance.

In order to arrive at an intelligent and thorough understanding of the origin and composition of soils, it will be necessary to devote a few pages to the consideration of the earth's crust as it presents itself to the eye of the geologist. The two great heads under which he arranges the whole series of rocks which compose this crust or outer covering are the *stratified and unstratified.* The stratified rocks, which are also sometimes called aqueous or sedimentary, are arranged in regular layers, or strata, and they owe their origin principally to aqueous agencies, being for the most part deposited in horizontal positions. The unstratified, on the other hand, being chiefly of igneous origin, show no such lines of deposition, but occur in irregular masses more or less crystalline in their composition, and breaking through and disrupting the regular strata. On account of the absence of any regular or determinate form, these masses are called amorphous.

Stratified rocks, when undisturbed by volcanic agencies, occupy horizontal or nearly horizontal positions, varying very considerably in depth or thickness upon different parts of the earth's surface. But owing to the various disturbing elements at work in the bowels of the earth, these rocks are found with every variety of form, position, and inclination. A glance at the annexed Fig. 1 will show some of these positions, in which Nos. 1, 3, and 7 represent masses of igenous rocks

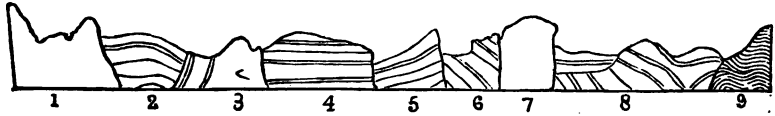


FIG. 1.

breaking through the stratified ones; 2, stratified rocks in different positions; 4, 5, and 6, horizontal and inclined stratification; 8, unconformable, and 9, contorted. Such formations are to be seen daily in the various sections presented to the railway traveller in the cuttings in different parts of the country. The strata dip at various angles, and where they come to the surface they are said to *outcrop*, the line of outcrop being called the *strike*. When the tilted strata dip in opposite directions from a given point, and lie in the form of the roof of a house, the axis is called an *anticlinal;* and when the point of meeting forms a trough or hollow, the axis forms a *synclinal*.

Fig. 2 represents the order of succession or superposition of the principal rock formations upon the earth's surface. But from this it is not to be inferred that these cover one another in regular layers like the coats of an onion, or

FIG. 2.

that by boring through the crust of the globe we should arrive successively at each formation. The order of succession which is here indicated is the order of time, and when two or more of the systems are found in the same locality,

they invariably maintain the same order of position; thus the chalk will always be above the oolite, the oolite above the coal, and the coal or carboniferous system above the Old Red Sandstone. One or more of the systems may be entirely absent: for example, in Kent the tertiary strata immediately overlie the chalk; in Yorkshire the oolite is found immediately above the New Red Sandstone, and the chalk close upon the oolite, while in some parts of Scotland the carboniferous system follows close upon the Old Red. This order of position, though of more use practically to the geologist, the mineralogist, and the student of paleontology than to the practical forester, is not to be lost sight of even by the latter.

A brief sketch of the various rock systems in the order in which they are indicated upon Fig. 2 will now be given.

1. **The Various Rock Systems.—Igneous Rocks.**—These may be said to occupy no determinate position, and to observe no order of superposition. In most cases they break through and derange or overflow the stratified rocks. Their origin is accounted for by various geologists in one of two ways; first, mechanical, as being the result of a great central fire; secondly, chemical, as resulting from heat evolved by chemical combinations. Igneous rocks are divided into three classes. *Granite* is so called from its having a granular composition. It forms as it were the foundation or the floor of the stratified rocks, and consists of quartz, felspar, and mica, all of which are crystalline in their formation. This rock forms the skeleton or framework of the principal mountain ranges upon our globe—the Grampians in Scotland, the mountains of Cornwall, Devon, and Cumberland in England, of Wicklow in Ireland, the Alps, the Pyrenees, the Oural and Himalayan Mountains, the Andes, and many others. *Trap* is an igneous rock probably formed under water, and so named from the terraced or step-like appearance it presents in Sweden and some other countries. This rock is not so old as the granite, but is of pyrogeneous origin being in some instances full of cells, or presenting the appearance of volcanic ashes. The heaviest rocks of this kind are the basalts, which are generally columnar in shape, as at the Giant's Causeway and Fingal's Cave. The soils formed from these rocks are generally fertile. The *Volcanic* rocks, properly so called though formed since the end of the tertiary period, belong to the class of igneous rocks. They are composed of lava, obsidian, pumice-stone, and in some places, as in Sicily, large quantities of sulphur are obtained from them. The export of sulphur from Sicily alone is said to exceed 80,000 tons per annum.

To show the importance of the study of the chemical composition of rocks the following table of an analysis of granite is appended.

Granite consists of	Quartz	Silica.....	Silicon Oxygen
	Felspar	Silica.....	Silicon and Oxygen
		Alumina	Aluminium & Oxygen
		Potash	Potassium & Oxygen
	Mica	Silica.....	Silicon and Oxygen
		Magnesia	Magnesium & Oxygen
		Potash	Potassium & Oxygen
		Lime.....	Calcium and Oxygen
		Peroxide of Iron	Iron and Oxygen

2. **Metamorphic.**—These rocks are also called hypozoic, on account of their being below or under the fossil-bearing strata, and azoic for their being supposed to be destitute of life. Their name indicates that they have undergone a change since their original deposition. This may be the result either of pressure, of heat, or of chemical agency, or of all these causes combined. Many of them are highly crystalline. They are the lowest stratified rocks, and are on this account called primary. They consist of four tolerably distinct groups. *Gneiss* is a very hard, tough, and crystalline rock, composed mainly of quartz, mica, felspar, and Hornblende. Though somewhat similar to granite in its appearance, gneiss never sends dykes or veins into the adjoining strata as granite does. From the tendency of gneiss to split or divide into layers in one direction it is said to be fissile. *Quartz Rock* exists in extensive masses in the Highlands of Scotland. As its structure is less contorted than that of gneiss, its lines of stratification are more distinctly marked. The granular portions of quartz are separated by layers or flakes of mica. *Mica Schist* is more finely laminated than the other two rocks, and the layers of mica give it the appearance of a succession of flakes or scales. *Clay Slate*, the fourth in succession in the series is familiar to us in the form of roofing slates of various colours and textures. It was originally deposited as a very fine clay or silt, being afterwards subjected to various changes. It contains few minerals, though crude iron pyrites are sometimes imbedded in it. The clay slate is found with the Mica Schist in Cumberland, in Wales, and in the Scottish Highlands. Clay slate districts are often picturesque, but generally barren.

3. **The Silurian System** is so called from its composing the rocks of that district in this country which was formerly inhabited by the Silures. The strata is for the most part slaty and shaly, and includes some limestones, sandstones, and conglomerates of pebbles and gritstones. Parts of this system have been

named the Cambrian, because found in North Wales, and the Cumbrian, from their presence in the lake districts of Cumberland. The whole formation is sometimes spoken of as the Greywacké or Transition, and its principal development is in the counties of Shropshire, Radnorshire, and Montgomeryshire. The Silurian system is sometimes divided into *lower and upper*. The conditions under which they were deposited are distinctly traceable upon the various beds of this formation. The fine lamination of some layers show that they were deposited in tranquil waters, while others bear the marks of tides and currents. In some of its calcareous strata are found corals and shells, and the richest auriferous veins in the world, such as those of California, New Zealand, Australia, and the Ourals, are in Silurian Schists. It supplies the builder with paving stones, building materials, marble, limestones, slates of an inferior kind, and many of the choicest metals.

4. **The Devonian System** is also called the Old Red Sandstone, the former name being assigned to it from its typical development in Devonshire. Its boundaries are distinctly marked in Geology, as its lower strata present the first remains of fishes, and its upper are nearly destitute of the vegetable remains which appear so abundantly in the succeeding formation. It consists mainly of sandstones and conglomerates. In Canada it furnishes thin seams of coal. Its colour shows that the waters in which this system was deposited must have been largely impregnated with iron. Some portions of the surface of this formation, especially in Herefordshire and Worcestershire, are of a loose, rich, loamy nature, and here luxuriant crops of corn and hops are obtained, orchards of apple and pear trees flourish, and the oak and the elm attain large dimensions. Lime is found especially useful in the preparation of this land either for corn crops or for plantations of timber trees.

5. **The Carboniferous System,** or system of the Coal Measures, holds an intermediate position between the old and the new red sandstones, and is remarkable for its profusion of carbonized vegetable matter. Its three main divisions are the Lower Coal Measures, the mountain limestone, and the Upper Coal Measures. Wherever found, the system is distinguished by an abundance of fossils. It contains some portions of all the preceding rocks from the granite to the old red sandstone. Bituminous coal and bands of ironstone are also found in it. The *Lower Coal Measures* are several thousands of feet thick both in Ireland and Scotland, and these are sometimes found to consist of a carboniferous slate. In Nova Scotia they produce beds of gypsum. The *Mountain Limestone* is so called because it forms the material of some of

the largest hills in the system, as the Peak in Derbyshire, the Mendip and Yorkshire hills. It often flanks or crowns hills of trap rock. Its soil is often thin and dark and peaty in character, producing a short sweet herbage. A common fossil of this formation is the coprolite of commerce. The *Upper Coal Measures* supply the coal in common use throughout the country. The gigantic flora of this period, and the pines, tree-ferns, reeds, palms, etc., abound in the formation, which is the result of submerged forests, and the produce of dense jungles and peat swamps. The clay soils on this formation are generally very wet, and where the sandy covering is siliceous in its composition, the soil is a poor one.

6. **The Permian System** derives its name from Perm, a district in Russia, where it is chiefly developed. It embraces the *Magnesian Limestone* and the *Lower New Red Sandstone.* Its fossils are similar to those of the coal measures. The remains of the stems of trees seem to indicate that these were principally coniferous kinds, having leaves similar to those of the fan palm. This system abounds in shales of various colours, limestones of a yellow colour, and containing considerable quantities of magnesia. In Durham and Yorkshire this system yields gypseous marls and calcareous flagstones. The soil is generally of a red clayey loam, well adapted to pastures and the growth of timber.

7. **The Triassic System** of rocks is the Upper New Red Sandstone of England, consisting of clays and marls, of a red colour, with beds of rock-salt and gypsum, and shelly limestone. In some places, as in Cheshire and Worcestershire, this system yields an abundance of salt. Around Nantwich in Cheshire, the rock-salt is found in beds of 75 and 100 feet thick respectively, and these are separated by coloured marls 30 feet in thickness. This system is characterized by a paucity of fossil remains, the result probably of the superabundance of saline matters in the waters of its deposition.

8. **The Oolitic System** embraces the rocks known as the Lias, the Oolite, and the Wealden groups. The *Lias* is an immense bed of clay containing layers or laminations of stone running through it. This stone is a dark argillaceous limestone, giving to the quarries from which it is dug a striped appearance when viewed from a distance. These bands are sometimes found to contain the lustrous coal, which takes so high a polish, and is known by the name of jet. It bears evidences of having been deposited in deep waters. Its principal development in England is from Lyme Regis in Dorset, through Bath, Gloucester, Leicester, and Gainsborough, to Whitby in Yorkshire. It affords

a good soil for general cultivation. Open surface drains have been found efficacious in keeping it sufficiently dry to carry heavy crops. The *Oolite* consists largely of rounded grains of carbonate of lime, which in shape resemble the roe of a fish. Like the lias it stretches in England from Dorset to Yorkshire, its place being above the layers of the former system. It contains the remains of cypress trees, yews, and araucarias, and produces fuller's-earth, the forest marble, and cornbrash limestone. The hills of this formation are like table-lands in appearance. The *Wealden* group is so named from its prevalence in the wealds of Kent and the wolds of Sussex. Here it appears to occupy the bed of an ancient estuary. It contains beds of a shelly limestone, a freshwater formation know as Sussex marble. This formation is largely planted with woods on account of the difficulty and expense of its cultivation. It is sometimes called the "Oak Tree Clay."

9. **The Cretaceous System** consists of the Chalk and Greensand groups, and contains dark marly clays, marine sands, and very thick beds of chalk. Its blue marly clays are known by the name of gault, and its sandy beds, which are green from chloritic matter, are called greensands. *Chalk* consists of the upper and lower systems, and of chalk marls. The upper chalks are soft and very white, containing layers of flintstones. The lower chalk is harder, darker, and more free from flints than the upper beds. In some places, as in the north of England, it is of a redder colour, and contains an abundance of flints. The lower chalk generally supplies the best builder's lime, and the upper, the best for agricultural purposes. Chalk hills are often of great elevation, rounded at their summits, and steep on one or both sides. The beech tree flourishes upon this formation. *Greensand* consists of the upper and lower layers, which are separated by a stratum of gault; the upper greensand contains beds of firestone in Surrey, which are of a greenish or grey colour, and are much used as hearthstones. The gault is a chalky clay, effervescing freely when tested with an acid. The lower greensands contain the Kentish Rag, which is quarried largely both for building purposes and for road metal.

10. **Tertiary** rocks embrace what are known as the Eocene, Miocene, Pliocene, and Pleistocene formations. These rocks are intermediate between the chalk and the drift periods. London and Paris are situated upon the *Eocene* formation. Beds of rolled flints, sands, shingle, gypsum, iron pyrites, sandy clays, and siliceous nodules, abound in this system. The *Miocene* is very sparely represented in British strata, though the lignites found in Antrim are classed under this head. The *Pliocene* consists of a coralline-crag, the red or ferruginous

crag of Norfolk and Suffolk, and rocks in the same counties which contain the bones of large mammals. The *Pleistocene* is the period of the boulder or glacial drift. The formations of this period consist of boulders, clay, sand, and gravel, which overlie the true tertiaries. Some of these boulders, many tons in weight, are perched high upon hill sides and summits, where they must have been deposited by passing icebergs.

11. **The Post Tertiary**, or Recent period, embraces all the formations which have taken place upon the earth's surface from the close of a glacial drift down to the present time. Some of these, such as the formation of coral reefs, the work of minute infusoriæ, the growth of peat mosses, the discharges of lava and scoriæ from volcanoes, the drifting of sands by the winds, the silting up of lakes and estuaries, the formation of marl beds and saline deposits, though insignificant in themselves, are jointly productive of immense results upon the face of the globe. The alluvial soils of this period form the rich marsh and pasture lands of the country. These for the most part consist of successive layers of mud brought down by the rivers and floods and deposited by the action of the tides. As the velocity of streams decrease they deposit first the rough gravel, then the finer gravel and sand, and lastly the mud which they have brought down from the higher grounds.

The Metamorphic rocks have been already spoken of as the hypozoic, on account of their being destitute of fossil remains. The succeeding four systems from the Silurian to the Permian are called Palæozoic, because they contain the remains of ancient life; the next three from the Triassic to the Chalk, Mesozoic, as indicating middle life remains; and the Tertiary and Recent, or Post Tertiary systems, Kainozoic, from their containing fossils of recent and existing species both of animals and plant.

The manner in which lake beds and estuaries become silted or filled up by accumulations of gravel, sand, and mud, brought down by streams and floods is shown in Fig. 3, where a river is supposed to run into and pass through a lake, depositing the matters held in suspension or rolled along by the force of the current in successive layers according to their gravity.

Although in Fig. 2 the successive rock formations are exhibited in the order of their superposition, it is not to be supposed that a section of the earth's crust would in any part of the world show a complete series: all that can be inferred is that whatever rocks are met with will always be found to occupy the same relative positions, a lower formation never overlying a higher one.

Fig. 4 presents to the view a section of the country from London to Brighton,

and affords an excellent example of the manner in which the upper strata are disrupted, and the whole conformation of a country changed by the upheaval of the lower strata of rocks. The dotted line running across the sketch from left

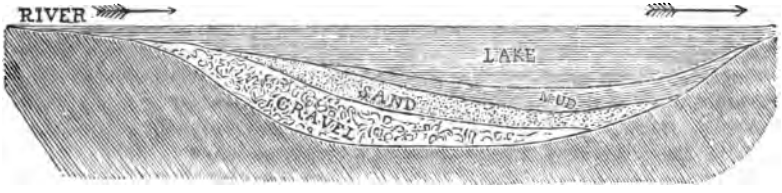


FIG. 3.

to right indicates high water mark. The figures 1 to 6 denote the successive layers of rock, etc., which underlie the district, and all of which crop out at various points; and the letters stand for the names of the various towns and places passed in going from one point to the other.

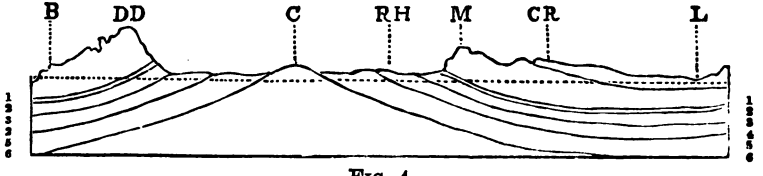


FIG. 4.

L shows the position of the London clay which underlies the city to a depth of about 300 feet. Through this runs the river Thames; and the clay, rising into a hill at Hampstead on the north of London, is there found to form a heath, being capped with a siliceous sand and gravel. On the south of London and at New Cross, this same clay is covered with a fine herbage and timber trees. Below this bed of clay is the chalk formation, which is here 700 feet thick, and is marked 2 on the section. No. 3 represents a thin band of firestone; then follows another thick bed of clay called gault, No. 4. This is followed by greensand, No. 5, and the wealden formation, No. 6. As these layers crop out successively between London and Brighton, they give a great variety to the face of the country. The letters upon the section taken in succession from right to left indicate the positions and elevations of London, Croydon, Merstham,

Red Hill, Coldstaple, Devil's Dyke, and Brighton. Starting from London the traveller soon after passing Croydon finds that the clay of the top soil receives an admixture of chalk from the subsoil, and is thereby much improved. Reaching the chalk formation, this is found to rise to a height of 525 feet at Merstham, forming in that neighbourhood, and at Reigate, a down land which just affords a fair herbage for flocks of sheep. In the village of Merstham, and at the foot of the chalk hills we observe an outcrop of the firestone which is in itself unimportant. Arriving upon the gault a little farther to the south, we again find a luxuriant growth of timber trees. This strong clay is of itself very difficult to work; but with an admixture of chalk, sand, and gravel, it assumes a loamy texture, and carries good crops of corn and hops. At Red Hill the greensand comes to the surface, and both here and at Leith Hill it forms large wastes consisting of sands of various colours, the rich foliage of the preceding formation having now disappeared. Passing onwards we reach the outcrop of the wealden formation, which, with what is locally termed the forest strata, extends from Crawley to Coldstaple, once the site of large forests, and now covered in places with flourishing plantations of larch. Much of the forest timber was used for the large smelting furnaces which existed throughout this district. On reaching the great saddleback or anticlinal of Coldstaple, a height of 280 feet above the level of the sea, and passing onwards towards Brighton, the same formations have again to be crossed, but in exactly the reverse order. At Devil's Dyke the hills of chalk reach a height of 640 feet, and then gradually fall away to Brighton, where near the sea-level the London clay again reappears in a small spot.

An examination of such a section as the preceding affords to the student of rock formations and their resultant soils, abundant opportunities of contrasting the capabilities of soils whether for the growth of cereal or timber crops. It also affords a clue to the origin of Artesian wells and springs of water in many localities. The chalk formation is well known to be porous, and to contain large bodies of the purest water. Whatever water enters this system between Merstham and Croydon must afterwards pass under the London clay which occupies the surface from the latter place to the city. And as no springs can make their way upwards through this impervious bed, it is only by boring that water can be reached; but when once the chalk beds are touched the supply is constant.

FORMATION AND INFLUENCE OF SOILS.

Having given a brief account of the principal rock formations to which soils owe their origin, it now remains to describe the methods by which those soils are formed, and the various natural agencies by whose combined influences the results are obtained.

It has been already remarked (*ante*, p. 9.) that attraction is the principal agent in bringing together the various substances, and that chemical attraction or affinity produces marked changes in the substances so combined. The attraction of gravitation, on the other hand, aided by various physical and chemical causes, tends to overcome the attraction of cohesion in all substances upon the surface of the earth, and to deposit them at the lowest levels. Among the most powerful chemical agencies may be mentioned *atmospheric oxygen*, which enters and causes the disruption of all rocks containing iron. This is particularly observable in basaltic rocks. The atmospheric influence is shown by the brown or dark-coloured veins which traverse these rocks. The *carbonic acid* of the atmosphere has also a powerful effect upon limestone rocks. A familiar instance of this is shown by the stalactites with which many of the caves in such rocks abound. These chemical agencies are active, not only as gases entering into and dissolving the surface of rocks, but also as hot vapours and steam, or springs, bringing up matters in solution. Thus chalybeate springs bring up iron; calcareous springs, lime; and silicious springs, flinty matters; while salt springs deposit saline matter, and volcanoes eject sulphur, scoriæ, &c.

Moss and lichen seeds floating in the air become deposited upon rocks, where they obtain light, heat, and moisture, and quickly germinate, their roots striking into and opening the rock surfaces, which are kept moist by the covering. As vegetable and even animal remains become successively deposited the soil deepens, higher forms of life spring up, until at length even the highest forms are sustained. Familiar instances of this kind are to be met with in some of the mountainous districts of Wales at the present day, where soils have been formed by the decay of lichens and mosses, followed by a growth of heaths, which in their turn have given place to furze or gorse. Thus in the course of ages a deep pasture, and even a fair arable soil is formed The pod containing the gorse seed, as soon as it becomes ripe, opens with a jerk during the heat of the day, projecting the seeds to a considerable distance from the parent plant, thus extending the range of growth year by year.

The most powerful and universal of the mechanical causes which favour the formation of soils is *gravitation*, which acts as soon as chemical agencies have to a certain extent overcome the power of cohesion; rocks tumble down into valleys, and are scattered upon the plains, where they are soon covered with life; at the same time winds move the finer particles from place to place. Upon the shores of the Baltic the sand is thus continually drifting, and on the south-west coast of France the *dunes* encroach so fast that artificial means have to be resorted to in order to stop their encroachments.

Water has been already spoken of as an active agent in the formation of soils. As it falls through the atmosphere it carries with it portions of carbonic acid gas, and as the water enters the rock this first dissolves the carbonate of lime contained in it, and then carries it away as more water enters. Besides rain-water, the aqueous agents act as streams, rivers, waves, tides, and deep-sea currents. Their operations may be observed in the bed of the smallest brook as well as in the deep mountain gorge which has been scooped out by their agency. Their powers of excavating and transporting materials are proportioned to their velocities, and also dependent upon the nature of the materials over which they flow. The substances which they roll along or hold in suspension are deposited in the order of their gravity—first the larger shingle, then the gravel, next the sand, and lastly the mud.

Water containing carbonic acid is also found to act strongly upon granite and felspar, and all rocks containing silicate of alumina combined with alkaline silicates, thus producing silicates and carbonates of potash and soda. The oxygen also acts in the form of oxides upon the rocks which contain iron, and upon the basaltic rocks. It should be remarked that while carbonic acid has a powerful effect upon limestones, it does not act either upon the sandstones or quartz rocks. By the action of the waves and tides the materials of fallen cliffs and landslips are carried about and eroded as they travel, until they in turn form shingle and sand upon the coast.

Frost is another active agent in the production of soils by denuding rock surfaces, and this more especially in the higher latitudes. The water which enters the rocky surface expands under the influence of frost, and either bursts the rock asunder at once, or else so loosens it that it afterwards crumbles and falls away. In districts over which glaciers have travelled, or where the avalanche descends, the *débris* with which these are loaded become discharged in the valleys and upon the plains.

The igneous and aqueous agencies may be said to act in opposite directions;

the one producing upheaval and disruption by means of volcanoes, hot springs, and earthquakes; and the other, a wearing away and deposition.

When soils are deposited in or near the district of the rock formation from which they are derived, they differ from those rocks only in texture and the addition of organic matter. But as the particles of which they are composed are commonly washed from the hill-sides to the smaller streams, thence to the rivers, and finally deposited in estuaries, where the contributions of many such streams are intermingled, such soils are generally composed of a great variety of earthy and mineral matters.

Alluvial Soils consist for the most part of a succession of very thin layers of mud. Warping land, as adopted in Lincolnshire and Yorkshire, by which the sediment brought down by the rivers, and stirred up by the tides, is, with the aid of sluices and embankments, deposited upon the land, is only an artificial method of obtaining alluvial deposits. This is practised so successfully that upon some parts of the banks of the Humber eighteen inches of water deposit one inch of mud.

The greatest extent of alluvial soil in England is that which stretches from Lynn to Wisbeach, thence to Spalding, Boston, and Grimsby, afterwards following the mouths of the Don, Aire, Wharfe, and Ouse, and running from the north of the Humber along the Yorkshire coast as far as Bridlington. When an alluvial soil follows the course of a river, it is widest at its mouth, and gradually narrows in the direction of its source. There is a considerable extent of alluvial soil on either bank of the Thames, and another near Sandwich. Romney Marsh, from Hythe to Rye, consists almost entirely of marshy land and alluvial sands. There is also a large tract in the valley of the Severn.

Alluvium generally forms low-level districts, which in some places have to be embanked to keep out the sea. Partaking as it does of the nature of the rock from which it is washed down, it is composed of a marine silt at the mouth of the Ouse, and a sandy loam on the coasts of Norfolk, Lincoln, and Yorkshire. At Boston, in particular, it is a good rich loam resting upon clay. These soils are of the best quality when the *débris* brought down by the rivers are mixed with marine substances washed up by the tide. Infusoria are found in myriads at the mouths of rivers: these consist mainly of silica, and are found only within reach of the tide. They die and become buried in the mud. The alluvial soils are generally dry, easily cultivated, and very fertile, but they are considered too valuable for agricultural purposes to admit of their being very extensively planted with timber trees.

Peat is the production of decaying aquatic plants in a cold and wet soil. In it both animal and vegetable substances decay very slowly. The peat contains considerable proportions of the oxide of iron. It exists in the fens of Lincoln, Huntingdon, Norfolk, and Cambridgeshire, where it consists mainly of a peat moss. It also extends from Bridgwater to Wells, in Somerset. Good drainage is especially necessary before planting upon such soils, after which the moss sinks rapidly. Peat mosses and cypress swamps are striking instances of vegetable formations on a large scale; and these eventually become either lignite or true mineralized coal.

Before describing the other soils it may be advisable to give a few particulars with regard to the composition of soils in general, as these are of various kinds, and are known by different names, according to their constituents as determined by mechanical analysis.

A soil consisting mainly of one substance, such as chalk, which is composed of seven-eighths of this substance, or even larger proportions, is called a simple soil, and, as in this case, it may be adapted to the growth of but few kinds of timber trees. Mixed soils are those which afford the largest scope to the planter. And though the soil itself is the chief consideration at the outset, the subsoil is after all the main point where the production of matured timber is considered. Nearly all trees soon push their roots beyond the surface soil unless this be of great depth, after which their progress is largely dependent upon the subsoil. But few of the best class of timber trees flourish for any length of time upon land which has not a fairly porous subsoil.

The two principal mineral ingredients in most soils are *sand* and *clay*. Sand is nothing but very minute stones, gritty and hard to the touch, and with so little cohesion that it will neither hold water nor long maintain any given form. It is generally found in nature in combination with clay and the oxide of iron. When it effervesces upon the application of an acid it is called a calcareous sand, and this is much better adapted to withstand drought than a silicious sand. What are properly considered as silicious soils are rough to the touch and will scratch glass; the calcareous soils handle more smoothly, and will not scratch glass. The furruginous soils are generally either red, yellow, or of a rusty-brown—colours derived from the iron which they contain, and which becomes oxidized and forms rust when exposed to the atmosphere.

The sand and gravel found in soils vary greatly with the rocks from which they are derived: these are either quartz sands, calcareous sands, or else the finer particles of mica, granite, or felspar. By a careful chemical analysis we

discover in the finer portions alumina, silica, oxide of iron, potash, soda, magnesia, and traces of manganese and various acids. When exposed to the carbonic acid of the atmosphere mineral felspar decomposes slowly, changing into two new substances—potash and silica, both of which are essential to the growth of plants.

Clay, or Alumina, is the name given to the finer portions of mineral matter contained in a soil. It is a substance which is adhesive, compact, and tenacious, attracting and retaining considerable quantities of moisture, so that whatever animal and vegetable matters are put into it decay slowly. Without an admixture of silex it is barren.

Soils are generally classified according to their proportions of sand and clay. When these are nearly equal the soil is a loam. When the soil contains about 75 per cent. of clay and 25 per cent. of sand, it is a clayey loam; and when the quantities are nearly 75 per cent. of sand and 25 of clay, a sandy loam. A very simple experiment will enable us to ascertain the mechanical structure of a soil. By taking a given quantity and well stirring it in a small vessel of water, first allowing the sand to sink to the bottom, and then pouring off the water with the finer particles of clay in suspension; next allowing the clay to settle, and again pouring off the water, and afterwards drying both the sand and clay and weighing them, a mechanical analysis is made. Or by another method: take a porcelain vessel and boil half-an-ounce of the soil in half-a-pint of water; shake it well up, then allow it to stand one minute; pour off the water, which will contain the clay, and afterwards allow the clay to settle; then dry and weigh both sand and clay.

When more than one-twentieth of the weight of a soil consists of carbonate of lime it is called a *marl*, provided clay is also present in quantity not less than 20 and not more than 50 per cent. If more than one-fifth consists of carbonate of lime it is a calcareous soil. In order to ascertain the quantity of lime, take a small portion of the soil and heat it to redness to destroy all vegetable matter; then weigh out 100 grains and stir this up in half-a-pint of distilled water; add an ounce of hydrochloric acid, and allow the whole to stand for a few hours, giving it an occasional stirring, when carbonic acid will continue to rise in the form of bubbles. When the mixture becomes quiet pour off the clear water, dry the residue, heat it to redness, and afterwards weigh it; the loss represents approximately the weight of lime and carbonate of lime in the soil.

Soils consist of both organic and inorganic substances; and the latter,

which are also called mineral substances, are sometimes twelve or fourteen in number. For the successful growth of plants the mineral part of the soil should contain all the substances found in their ashes. The organic matter of a soil is valuable chiefly on account of its nitrogen. This organic matter varies very considerably, being in peaty soils from 50 to 70 per cent. of the whole, and sometimes reaching even to 97 per cent. In soils which have long been under cultivation it seldom exceeds 25, and in good wheat soils it comprises from 4 to 8 per cent. Some very rich alluvial soils, as those in the valley of the Nile, have only 5 per cent. of dry organic matter, while some of our rich clays have 10 or 12. Organic matter abounds in old pastures, and as it decays it supplies the roots of plants with ammonia and carbonic, ulmic, and humic acids.

To ascertain the proportion of organic matter in a soil, place one ounce of it upon paper in an oven heated so as not to char the paper; and after well drying it burn about 200 grains, and the loss in weight will show very nearly the percentage of organic matter.

The principal soils are named from the main ingredients in their composition: thus sand consists mainly of silica, and it may also contain small quantities of oxide of iron and lime; clay contains alumina and silica, and it may also have in its composition some lime, potash, soda, and phosphoric and sulphuric acids; while calcareous soils, or limestones, contain lime, and they may have also some silica, alumina, oxide of iron, potash, soda, and phosphoric and sulphuric acids. Their organic matters, besides humus and various vegetable and animal remains, are often rich in other substances.

Notwithstanding their diversity of appearances, all soils after burning show a great similarity in composition. The organic matters in them are not always to be taken as indications of their fertility, as some of the best wheat soils have been found to contain less than 4 per cent., while a sample of a good wheat soil from Midlothian contained 10.

Soils differ greatly in density, sand and marl being the heaviest, and peaty soil the lightest. On this account the latter are greatly benefited by a dressing of marl, or even sand.

1	cubic foot	of dry silicious or calcareous sand weighs ...	110 lbs.
1	,,	of soil, half sand and half clay	95 ,,
1	,,	of an ordinary soil, from	80 to 90 ,,
1	,,	of pure agricultural clay	75 ,,
1	,,	of good garden mould	70 ,,
1	,,	of light peaty soil	30 to 50 ,,

The sandy soils absorb but little water, while the aluminous ones take in a great deal, and peat still more. The shrinkage of a soil is an important point for the consideration of the planter and the farmer. Peats and strong clays, from taking in so much water, shrink considerably in drying, and in consequence of this during a drought the roots of plants growing in them become very much compressed, by which means air is excluded and vegetation receives a check. Hence the advantages of a mixture of sand and clay in the soil.

Nearly all soils possess the property of absorbing moisture from the atmosphere during the night,—clay when well dried to the extent of about one-thirtieth of its weight, and peat nearly one-twelfth. Dark-coloured soils become warm sooner than lighter ones, and are in consequence more fertile. Sir Humphrey Davy found that a rich black mould, containing about one-fourth of its bulk of vegetable matter, had its temperature raised from 65° to 80° in the sunshine in an hour, whilst chalk so exposed only reached 69°. The heat received depends to some extent upon the inclination of the surface of the land, that which faces the sun absorbing most. All clays heat very slowly and cool rapidly. Humus retains but little heat, while a slaty marl, though containing a considerable quantity of water, heats rapidly and is consequently fertile.

With reference to their capabilities for timber growing, Dr. James Brown divides Great Britain into six districts, and for these he claims advantages in the order in which they are hereafter enumerated.

I. The great central and eastern plains of England and the valley of the Severn. II. The plains of Yorkshire and Cheshire. III. The tablelands situated to the south-west of the two former districts. IV. The table-lands of the north of England and the south of Scotland, extending from the Tees on the south to the Firth of Forth on the north. V. The narrow central plain in Scotland which extends from Glasgow, along both sides of the river Forth to Edinburgh, and thence northwards as far as Montrose. VI. The low-lying lands on both sides of the Moray Frith. These are considered more particularly in relation to their capabilities for the growth of hard woods, as the pine and fir tribes produce more valuable timber to the north of the central plane of Scotland,—at Dunkeld, Taymouth, Glenmore, Abernethy and Braemar.

The following classifications of soils may be found serviceable to the forester who wishes to study them in relation to their capabilities for the purposes of timber growing.

CLASSIFICATION OF SOILS.

1. **The Clay Soils**, called also argillaceous, and situated upon the London clay formation, the plastic, the wealden, and also upon some of the coal measures, all of which have but little calcareous matter; and upon the gault, the Oxford or "clunch," and the blue lias, which have less silica than the preceding, but more calcareous matter. The London clay is generally of a bluish colour when wet, and it cracks very considerably in dry weather. It extends from Orford, in Suffolk, through Essex, Maldon, Romford, and Barking to London, and is also found in Windsor Park. It likewise extends into Hampshire, and appears on the coasts of Kent and Sussex—as at Sheppy and Reculver Hill in the former, and Brighton in the latter. Portions of the New Forest consist of this clay, from Lymington to Romsey. Another narrow strip runs from Southampton to Worthing. It thus comprises the greater part of Essex, nearly all Middlesex, and parts of Kent, Berks, and Hants. There are no springs in it, as it is impervious to water, and very tenacious.

The Wealden, or oak-tree clay, exists in Kent, Surrey, and Sussex, of a great variety of colours, very deep, and soft to the touch. Its surface is for the most part level. Being expensive to cultivate, it is pretty generally planted with woods. Oak trees up to about forty or fifty years old, as standards, with underwood, are here found to pay best, as the bark is of excellent quality, containing much tannin matter. Formed into small beds with good surface drainage, we here find it will grow good birch, ash, beech, hornbeam, and in places even Spanish chestnut. But in wet seasons the shoots of the latter do not ripen, and the larch for the most part roots so shallow that it blows down.

The Oxford clay belongs to the middle oolite. Both in Yorkshire and in the south of England it is found to be favourable to the growth of the oak. Some of the heavy clays upon the old red sandstone are renowned for the production of sturdy oaks—the "weeds of Herefordshire," as Murchison calls them.

2. **Calcareous Soils** are found upon the chalk marl, the oolite clay, and the Norfolk drift clay. Besides calcareous matter these contain silica and oxide of iron. The diluvium of the Oxford clay and blue lias is derived mainly from the coral rag and oolitic rocks, and consist of a calcareous gravel. The soils upon the chalk formations, and that derived from the shelly oolitic formation are only fragments of these calcareous rocks, with earthy matter and clay intermixed. The soils upon the lower oolite, coral rag, magnesian and carbo-

niferous limestones, contain considerable proportions of both silicious and ferruginous matters. The last four soils are open, dry, and easily worked. The chalk rises into large hills, and is of considerable breadth in many parts of England. One example of it occurs in this county, where it forms what is called the "backbone of Kent," and is about fifteen miles broad between Canterbury and Folkestone. It is generally a very open and dry soil. A kind of rubbly or rolled chalk is found in parts of Lincolnshire, Norfolk, and Suffolk.

3. **Silicious Soils** contain a large percentage of silica. They are found on a portion of the plastic clay formation, on the iron and Hastings sands, on the sands of the coal formation, and upon the old red sandstone and millstone grit. These consist of silicious sands and gravels, friable, loose, and dry, having little aluminous and no calcareous matters. The diluvium on both the plastic and wealden clays, and that of the drift on the new red and coal formations, consists of flinty gravels, with some clay and ferruginous matter. The soil on the new red and on the basaltic formations contains calcareous matter and oxide of iron, while that upon the greensand and the alluvial soils has a considerable portion of fine earthy matter, and particles of nearly all the rock formations through which the rivers run. Both consist of silicious, argillaceous, and calcareous matters and oxide of iron. The new red is a silicious sandstone, containing clay beds more or less marly in their composition. In Sherwood forest it exists as a red and yellow sand. It is found at Exeter and near Taunton, and extends from Torbay, through Gloucester, Worcester, and Nottingham, to the mouth of the Tees, being the most extensive system in England. In Devon and Somerset its soils are of first-rate quality, and they derive great benefit from liming. There is much rich meadow land upon this system. The old red is found in England, chiefly in Herefordshire and Monmouthshire. It has generally an uneven surface, and contains mica and silicious sands. The rock decays rapidly with exposure; upon the Dunstone portions large crops of apples and hops are grown. The openness of the subsoil adapts it to the growth of trees, and fine oak, elm, and ash are produced upon it.

In an uncultivated state trees appear to follow a natural rotation, and as soon as one kind dies off, or is felled or burnt down, another kind springs up. History tells us that when Charlemagne hunted in the forests of Gerardiner the trees were oak and beech, though at the present time they are pines only. On the banks of the Rhine natural oak forests several centuries old are giving way

to the beech, while oak and beech are also yielding to the pine. In the Jura and the Tyrol the beech and the pine alternate upon the same land. As forests of oak and maple are cut down in America, pines spring up; while upon the sites of old pine forests, the broad-leaved species appear. In Sweden, when a pine forest is burnt down, birch takes its place for a time, though the pines eventually reappear and gain the ascendency. These changes point to alterations in the soil, which go on slowly but surely, the results of partial exhaustion, excretions, and chemical changes.

Careful analysis of the composition of the wood of various kinds of timber trees, and of the ashes of the burnt wood and leaves, affords valuable information to the forester, but a concise treatise upon this subject is still a desideratum. The experiments of Messrs. Schoedler and Peterson have done something to pave the way. From numerous experiments upon wood of various kinds which had been dried at 212° Fahr., the ash being deducted, they found that in almost every instance carbon formed nearly 49 per cent., oxygen about 44, and hydrogen 6 per cent., while each sort contained a small portion of nitrogen. The average percentage of ash or inorganic matter after burning, was 1·5. This was the result of experiments tried upon oak, ash, beech, birch, elm, poplar, lime, willow, pine, and larch. The similarity of organic structure is wonderful. But with regard to inorganic matter, Johnston tells us that wood and leaves dried in the air produced—

From the	Elm	... ...	Wood	1·88	... ...	Leaves	11·8	per cent.
,,	Willow	...	,,	0·45	... ...	,,	8·23	,,
,,	Poplar	...	,,	1·97	... ...	,,	9·22	,,
,,	Beech	... ...	,,	0·36	... ...	,,	6·69	,,
,,	Oak	... ...	,,	0·21	... ...	,,	4·5	,,
,,	Birch	... ...	,,	0·34	... ...	,,	5·0	,,
,,	Pitch Pine	...	,,	0·25	... ...	,,	3·15	,,
,,	Common Furze		,,	0·82	... ...	,,	3·1	,,

It will be observed from this table that the leaves of the elm contain nearly six times as much inorganic matter per cent. as the wood, and the leaves of the oak twenty-two times as much. The willow and beech also contain about twenty times as much in the leaves as the wood, and these quantities are constant, whatever may be the soil and situation.

Though trees are, in the main, less dependent upon soil than upon elevation, temperature, and moisture—as the chestnut will flourish alike in calcareous and

clayey earths, in volcanic ashes, and in sand,—yet they are particular soils which are the best adapted to the growth of various trees, and upon which alone they attain their greatest perfection. And as it is not supposed that, except for the purposes of ornamental and screen planting, the superior agricultural soils will to any great extent be occupied by timber trees, it may be advisable to give a few examples of soil, which, with one or two exceptions, have been found better suited to the growth of trees than to the production of either corn or herbage.

Simple experiments, such as those already given, are all that are necessary to enable us to form a fairly correct idea of the adaptability of untried soils; while in most districts the existing growths will enable the forester to see at a glance what trees flourish and what languish upon a particular soil.

Qualitative analyses of soils are more difficult than quantitative. To test for iron, take a quarter of a pound of the soil and burn it in a crucible for an hour; then cool it, and well pound it in a mortar, and afterwards boil it in hydrochloric acid for about twenty minutes. Add ammonia to part of the filtrate until it begins to get cloudy, afterwards a drop of nitric acid, and another of ferrocyanide of potassium. The presence of iron will be shown by a dark blue precipitate. To test for alumina, add some potash to part of the filtrate, and again boil and filter, then add ammonia, and the alumina will be precipitated.

To ascertain the quantity of saline matter in a soil, take 2 lbs. of it when dried, boil this in a quart of distilled water, allow the matter to subside, then pour off the water and evaporate the soil to dryness. Weigh the remainder, and the loss will indicate the proportion of saline matter, which in a good soil may be about 20 grains.

Table of soils suited to the growth of trees generally.

1. Sandy or gravelly loams, chalky loam or gravelly chalk, light sandy or gravelly soils, loamy clay or clayey loam, heathy or moorish soil.	Resting on porous subsoils, rubble, loose sandstones, &c., &c.
2. Strong loamy or clay soils, sandy, gravelly, or loamy soil, very thin heathy or moorish soil.	Resting on retentive subsoils.

The following soils have been found best adapted to the particular species of trees which are named in connection with them:—

1. *A clayey loam* on a clay subsoil, consisting of nearly one-half fine sand,

one-tenth coarse gravel, one-fourth silex, and not less than one-sixtieth of oxide of iron. This is, *par excellence*, an oak-tree soil, though nearly every timber tree will flourish upon it.

2. *A moist clay soil* on clay, containing nearly one-half fine sand and coarse gravel, one-third silex, one-eighth alumina, and one-fortieth oxide of iron. This is found to suit trees somewhat in the order in which they are enumerated—oak, elm, ash, hornbeam, Norway spruce, pinaster, Weymouth pine, and after a good trenching the tulip-tree.

3. *Chalky soils*, consisting of about three-fourths of calcareous sand, one-eighth of carbonate of lime, one-fourteenth of silica, one-fortieth of alumina, and one-fiftieth of oxide of iron. Such soils are well adapted to the beech, and they will grow ash, and even oak, but they are not suited to resinous kinds.

4. *A sandy loam* resting on a silicious sand, containing not less than one-eighth its bulk of silex, and one-thirtieth of alumina. The beech stands first on this soil, and the famous Woburn Abbey specimen figured by Pontey was growing upon such a soil, with a deep sandy bottom. Next in order of adaptability come the larch, pine, and fir tribes.

5. *Poor sandy soils*, resting either upon rough gravels or shale, and having one-twentieth of silex, with a proportion of oxide of iron and alumina. These will grow pine, larch, spruce, sycamore, and birch.

6. *Silicious sandy* or heathy soil, resting either upon shale or upon ferruginous stones, its vegetable matter being derived from the decaying heath to the amount of about one-eighth of its entire bulk, and also containing about one-fortieth of silex. This soil is suited to the birch and silver fir, and, if it rests upon a deep sand, to the beech also.

7. *Silicious sandy soil* resting upon a damp but not a wet subsoil, and consisting of one-tenth of calcareous gravel and one-tenth of silica. This suits the oak, and also the Spanish chestnut. It also produces elm of superior quality, but of slow growth. Upon such a soil the silver fir grows best as a nurse, and next to that the larch and spruce.

8. *Peat moss*, resting on a bottom of clay or marl, and being composed of about one-half fine silicious sand, one-sixth vegetable fibre, one-tenth silex, and one-fortieth alumina. This is generally very wet, but after drainage it will grow the birch, the poplar, the abele, the willow, and even the Scotch fir. The drainage is all the more necessary as peaty soils are generally formed in situations from which water cannot escape, and they are consequently the produce of moss and aquatic vegetation. As matter decays further growth is

encouraged, until at last it reaches the height at which the water escapes. After this, plants of a more woody kind get hold of the soil.

The following table, taken from the *Cyclopædia of Agriculture*, by the kind permission of its editor, John Chalmers Morton, Esq., exhibits the composition of the ash of a few of our most extensively cultivated trees. When considered in conjunction with the preceding remarks upon soils and their constituents, it will enable the student to form some idea of the intimate relations existing between the composition of the inorganic matter of the soil and the ashes of plants :—

Names of Plants or of their parts.		Ash in 100 parts.	Potash.	Soda.	Magnesia.	Lime.	Phosphoric Acid.	Sulphuric Acid.	Silica.	Peroxide of Iron.	Chloride of Sodium.	Chloride of Potassium.	Remarks.
Beech	wood...	—	11·80	2·04	8 42	47·25	3·29	1·01	1·09	0·60	0·16		
	seeds...	—	22·82	9·50	11·64	24·50	20·81	2·20	1·88	2·67	0·87		
Oak	wood...	—	5·65	3·77	3·01	50·58	2·32	0·78	0·52	0·38	0·02		
	seeds...	—	64·64	—	5·57	6·86	19·19	—	0·96	1·89	0·98		
Elm	wood...	—	21·92	13·72	7·71	47·80	3·33	1·28	3·07	1·17			
	bark...	—	2·22	10·09	3·19	72·70	1·59	0·62	8·77	0·82			
Lime	bark...	—	16·14	4·53	8·03	60·81	4·02	0·75	2·27	1·24	2·21		
	wood...	—	35·80	5·23	4·15	29·93	4·85	5·30	5·26	7·97	1·49		Red oxide of manganese.
Pine	seeds...	—	22·37	1·26	15·09	1·86	—	10·44	10·44	3·01			
	wood...	0·14	2·79	15·99	19·76	31·74	1·93	3·04	3·04	3·51	1·48	1·48	18·17
Larch—													
Pinus larix,	wood...	—	15·24	7·27	24·50	26·97	1·79	3·60	3·60	4·25	0·92	0·92	13·15
,, picea,	seeds...	—	21·71	6·76	16·79	1·54	—	11·71	11·71	1·31	0·57	0·57	
,, sylvestris,	wood...	—	7·17	6·26	9·19	31·50	2·07	5·72	5·72	2·23	0·81	0·81	
Sabine,	wood...	0·85	0·83	3·29	2·97	77·82	2·42	0·39	0·39	1·36			

THE STRUCTURE, FUNCTIONS, AND FOOD OF PLANTS.

The elements of matter and their combinations in the atmosphere, in water, in rocks, soils, and plants, have already been treated of in the preceding pages : it now becomes necessary to add a few remarks upon the structure, the functions, and the food of plants. In order to place the matter more clearly before the reader, I will arrange these remarks under the following heads :—

1. *Simple Organs*—Cellular, Woody, and Vascular Tissues.
2. *Compound Organs* and their functions, subdivided into
   (*a*) *General Organs.*
   (*b*) *Organs of Nutrition*—the Root, Stem, Leaf-buds and Leaves, Sap, and Pith.

(*c*) *Organs of Reproduction*—Flower-buds, Flowers, Fruit, and Seeds.
(*d*) *Organs of Preservation*—Seed-shells, Bark.

3. *Germination of Seeds.*
4. *The Food of Plants.*
5. *The Classification of Plants and Trees.*
6. *The Distribution of Plants and Trees.*

Simple Organs.—Cellular Tissue consists of the succulent or fleshy parts of plants, such as fruits and the pulp of the leaves. Each cell is a small bag of oxygen and hydrogen, with a little starch, gluten, and colouring matter. The starch consists mainly of carbon, and the gluten of nitrogen. Small crystals of inorganic matter are also found, and these contain an acid. The cells in the epidermis contain air only. In the pulp of the fruit and in the pith they are not unlike a honeycomb; in the bark and sapwood they have the form of parallelograms. Among these cells are receptacles for the secretions and for air, and also inter-cellular passages, which have a direct communication through the skin with the air without. Cellular tissue decays rapidly as soon as it is separated from the tree; the carbon and oxygen escaping as carbonic acid gas, and the hydrogen attracting water from the atmosphere, and thus melting away, leaving only the small inorganic portion behind. As the pulpy part of the leaves is the first to disappear, the veins or nerves only remain behind, forming in many instances a beautiful network of woody fibre. The fleshy parts of the leaves, the flowers, and the fruits, are composed entirely of cellular tissue. The stones of fruits are of the same substance in combination with earthy matters.

Woody Tissue consists of very fine cells in the form of cylinders, and these are hollow tubes tapering at the ends. Through these when young the sap ascends, until at last they become filled up or choked with inorganic matters. This tissue is found mixed with the cellular in the wood and the inner bark of trees. It decays very slowly. In some plants the woody fibres are so very fine that seven or eight of them combined are no larger than a hair. This fibre forms a part of the veins and nerves of leaves, and it constitutes the principal part of those organs in which strength, toughness, and durability are required.

Vascular Tissue is composed of spiral vessels and ducts which are found in the flowers and leaves, and often in the young green wood. They are sometimes called air-vessels, and they may be distinctly seen in sections of the rattan, the oak, and the vine. Modern physiologists divide this tissue into vascular proper, pitted, and laticiferous. The first consists of very delicate

cylindrical cells, which contain spiral vessels and ducts. The spiral vessels are of great delicacy, and are found coiled up in the form of a corkscrew. By taking a young shoot of dogwood, and cutting it open, we may see the wonderful way in which such vessels may be unrolled. They are filled with air, which is remarkable for the quantity of oxygen it contains, being from seven to eight times as much as is common in the atmosphere. The ducts are cylindrical vessels in which the spiral tubes appear as if broken into rings. They will not unroll, and they are apparently intended to keep the membrane distended like the rings in the windpipes of animals. Pitted tissue is composed of tubes which, when held up to the light, show numerous holes or dots in their lining. The laticiferous tissue is filled with the latex, or small granules of descending sap. These vessels are found in the under veins of leaves, and within the liber, or inner bark.

Compound Organs.—The Epidermis is one of the most important of the general organs. It consists of a thin skin, or membrane, which covers every part of the terrestrial plant with the exception of the spongioles at the one end and the stigma at the other. It is composed of cellular tissue, the cells containing air, and not water. The main use of this skin seems to be to retain a sufficient quantity of moisture in the plant, and to effect this its thickness is curiously adapted to the plant's growth. Sometimes it consists of only two layers. The outermost, which is called the cuticle, is often very thin. Plants growing in very hot countries have three, and sometimes—as in the case of the oleander—even four layers, the object of these being to resist the heat of the climate and the dryness of the atmosphere. The inner bark of a tree is called the liber, and the solid part between this and the cuticle the cortical integument. The epidermis of most plants is full of stomata, or valve-like openings (shown in Fig. 5), which have communications with the intercellular passages, and which regulate the evaporation. When these pores are very numerous the plants require a large supply of water. In the leaves of the common lilac they are about 160,000 to the square inch of surface: hence the drooping appearance which this tree assumes during a very hot day. These stomata, or mouths, consist of two cells, which are kidney-shaped, and between which there is a very small slit, which closes when necessary. By means of the stomata the plant throws off superfluous water; and if plants which have but few of them are overwatered they are affected with a kind of dropsy, and soon decay.

Upon the epidermis of a plant is often found minute expansions in the form of hairs, which are either lymphatic or glandular. *Lymphatic hairs* are sometimes soft and downy, and occasionally they appear as hooks and barbs. Their

use appears to be partly to protect the plant from the sun and winds, and partly to collect moisture from the atmosphere. The latter opinion is favoured by their position, which, when they do not cover the whole surface of the leaf, is either along the veins or at the angles where the veins cross each other. *Glandular hairs* are hollow, and often open at their points, as in the nettle and the sweetbriar, in both of which plants they give off a volatile oil, which appears to be secreted at the base. Sometimes the hairs upon a plant are found hardened and pointed, as in prickles or thorns.

Roots are divided into tap-roots, fibrous, and creeping-roots. Most forest trees are fibrous rooted; but in some varieties of elms and in the poplar the roots take a more horizontal direction, and in form strongly resemble the creeping root. Roots consist of pith, wood, and bark—an arrangement of parts which in reality extends from the smallest radicle to the topmost spray of a tree. The *rootstock* is only an underground or creeping stem, of which class ginger is a product. What is commonly called a *creeping root* is more slender, as in that vegetable hydra—couch grass. The *cormus* is a short subterranean stem such as that of the crocus or the tulip. The *tuber* is also a short fleshy stem which runs or grows underground, and is covered with buds called eyes, as in the potato. The *bulb* is only a mass of rounded scales packed very closely one over the other, and having roots at the base, as in the onion.

Roots fix the plants in the soil, or to whatever they may be growing upon. Through the small openings of the extremities of their sponglets, or radicles, they also take in most of the inorganic parts of plants in a state of solution. They likewise give off secretions from the plant, and it is mainly on this account, and not so much as is generally supposed from exhaustion of the soil, that the same species of trees will not generally follow each other. This is found to be the case in a marked degree with the apple-tree. Roots have neither leaves nor buds, and very seldom any scales. They are the principal organs of nutrition. The main root, growing downwards from the *collum*, or neck of the tree, is called the tap-root, and in the early stages of growth this is the principal support. The chief supporting roots are also known by the name of the caudex, and the smaller ones fibrils, or fibrous roots. With the exception of its extremities the whole root is covered with an epidermis, which is destitute of pores—a fact which should point out the necessity of taking great care to secure the whole of these uninjured in the operation of transplanting. Short-lived plants, such as annuals and many herbaceous plants, are dependent for their nourishment mainly upon their tap-roots.

Stems rise direct from the soil, and are commonly divided into branches. In herbs they are generally succulent, and rapidly perishable; in shrubs and trees, woody and generally covered with bark, more or less rugged. In the trees of tropical regions, such as the palm-tree, the stem or trunk is cylindrical, bearing leaves only upon its summit. Sometimes it is only a delicate thread, as in the strawberry; occasionally the stem is seen twining round other trees, as in the woodbine and the hop. It is either solid, as in the oak and elm; or hollow, as in umbellifers and in grasses. In the kohl-rabi it is very short, and bears a close resemblance to a turnip, having buds upon its sides. In the cactus the stem is very flat and leafy-limbed; in the geranium it is jointed, or articulated, such joints being more or less swollen and liable to snap asunder. With the internal modifications of stem we shall have to deal more particularly when we come to consider the classifications of plants.

The **Buds**, or **Branches**, proceed from the axils of the leaves or where these join the stem. They first appear as small scales only, but afterwards develop into branches, forming the head of the tree and supporting its appendages. From the small conical buds, which are afterwards surrounded by minute scales, and which are in reality the growing points of the tree, proceed these branches. In exogens they appear either at the termination of the pith or at the outer mouths of the medullary processes. In endogens they likewise proceed from a pulpy substance inside the trunk. By means of the leaves with which the branches are covered they obtain supplies of elaborated sap for the sustenance and increase of the portions of the trunk immediately below them; so that this becomes pretty equally distributed throughout that length of bole which happens to be between two whorls of branches. To this property of the branches must be attributed the conical shapes of all trunks which are well furnished with branches throughout their whole length. Hence also the cylindrical forms, and the regular increase in size of those which have no branches for a considerable distance from the ground, and the uniformity of size which is maintained throughout that length which lies between two regular tiers of branches. To the want of a proper knowledge of these facts must be attributed the indiscriminate lopping off of branches by those who early in the present century considered them as mere "robbers of the trunk."

Leaves in their first stages are simply expansions of the stem. A leaf consists of two parts—the stalk and the blade. Such as have no stalk are said to be sessile. Leaves are composed of ribs and veins, and when they form a network they are said to be reticulated (Fig. 6), as in the oak and the apple-tree. When

the veins form a succession of forks, but do not run into each other, they are called fork-veined, as in Fig. 8; and when the veins run side by side, as in grasses, the leaves are parallel veined. Simple leaves are such as are divided in their structure but not separated into distinct parts, such as the willow and the sycamore. But when they consist of a number of distinct pieces, as in ash, they are called compound. When growing in pairs, exactly opposite each other, they are said to be opposite-leaved; and if more than one pair stands in opposition they are verticillate. When not upon the same level leaves are alternate.

Some of the various forms and names of leaves are shown in Fig. 7. Those which are subdivided upon the same plan as the primitive form are distinguished by a prefix which denotes the number of such subdivisions. Some acquaintance with the forms and names of leaves is one of the first essentials

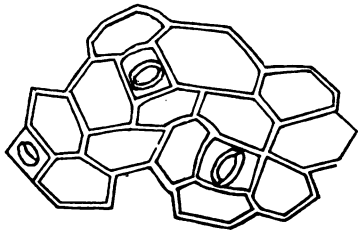


FIG. 5.

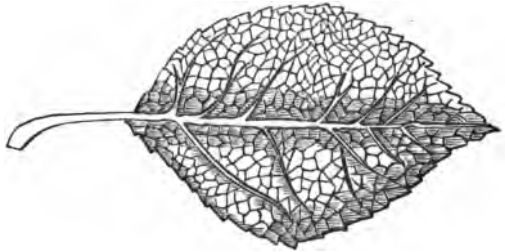


FIG. 6.

for a young forester who may wish to increase his store of knowledge by consulting botanical works. The following are the more common forms:—1, linear; 2, lanceolate; 3, oval; 4, oblong; 5, orbicular; 6, ovate; 7, obovate; 8, cordate; 9, reniform; 10, saggitate; 11, hastate; 12, ternate; 13, palmate; 14, digitate; 15, pedate; 16, sinuate; 17, lyrate; 18, panduriform; 19, pinnatifid; 20, abruptly pinnate; 21, unequally pinnate.

Compounded leaves are named from ternate, biternate, and triternate; from pinnate, bipinnate, tripinnate, etc.

Sometimes the midrib of a leaf is found to be very much elongated, and possessed of the power of twining itself around branches or whatever comes in its way, in which case it is called a tendril. The leaves act as a laboratory for the sap, and they are also furnished with respiratory organs, thus fulfilling the double purpose of both lungs and stomach to a plant. They take in carbonic

acid, separating the carbon and the oxygen—retaining the former, and giving back the latter. Leaves consist of an upper and under surface, which are very

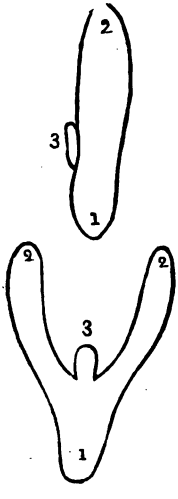


FIG. 10.

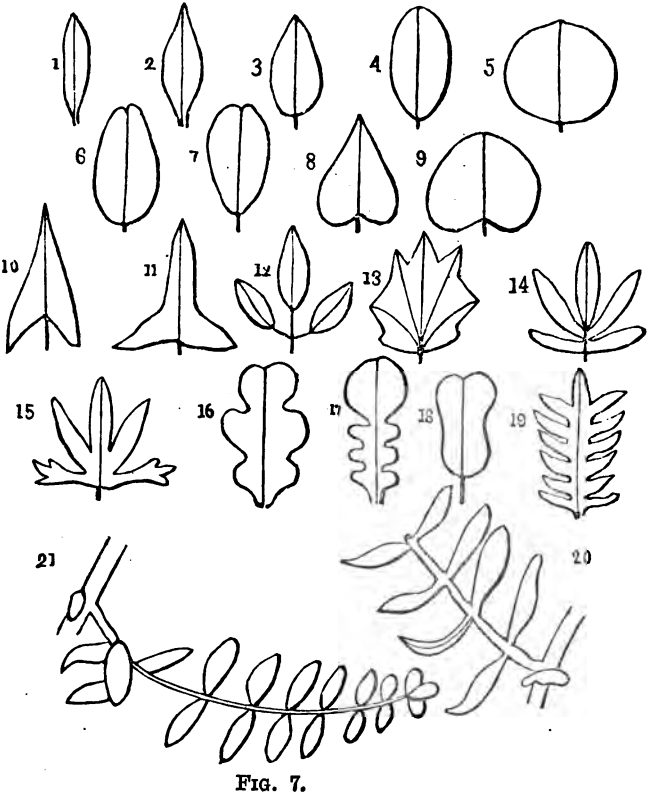


FIG. 7.

different, both in colour and texture. The venation also is widely different in the varieties of leaves.

Sap is of two kinds—that which ascends in the plant and which is known by

the name of crude sap, and that which descends and is called elaborated sap. As the sap ascends it is thin and watery, and generally sweet in taste, and even in the most poisonous plants this is found to be innoxious. This is proved in the case of the euphorbia of the Canary Islands, the descending sap of which is so acrid and caustic as to burn the flesh of those who touch it; and yet the natives tear off the bark of the tree and obtain a refreshing drink from the alburnum in the spring time.

FIG. 8.

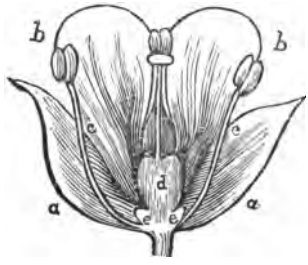


FIG. 9.

When the leaves of a tree are fully developed the sap begins to descend by the latex, the vessels of which are found upon the under sides of the leaves and form a lining to the inner bark. It thus happens that the principal secretions of a tree are either deposited in the bark or carried down to the roots. The laticiferous tissue consists of branched tubes filled with a mucilaginous fluid, which is the descending sap. From this latex is formed sugar, gum, tannin, and other secretions.

The ascending sap passes through the soft or sap wood, spreading horizontally at the same time that it rises vertically in the plant, and carrying earthy matter to the heartwood. The experiments of Knight have proved that the sap undergoes a change as it ascends the vessels of the alburnum, and before it comes under the action of the leaves. This is shown by the fact that the sap obtained from the lower part of a tree yields less saccharine matter than that drawn from the upper part of the stem. From the ascending sap in the birch, elm, and beech, may be obtained water, sugar, mucilage, extract, acetic acid, potash, and lime. Saccharine matter is most abundant in the birch and the sugar-maple. The whole theory is, however, one still requiring careful study

and abundant experiments for its complete elucidation; for as the sap rises in the stock it may, according to the organic structure of the upper part, produce either the sour crab or the sweet and aromatic pippin.

Through the medium of this sap there is conveyed to every plant substances which it cannot assimilate. As this is mainly inorganic matter it becomes deposited in the vascular tissues of the petioles and leaf-veins until it chokes them up, and the leaves consequently wither and fall off. In this way may we account for the large proportions of inorganic matter found in the ashes from the leaves of many forest trees, and already explained in the table given upon p. 42.

The Pith forms the central part of roots, stems, and branches. It is cellular, membraneous, and silvery-white in colour. As the tree advances in age the pith loses its spongy texture mainly through the compression of its cells. Its action is continued in the young wood of branches long after it disappears in the older parts. By pruning off close to the stem a branch from which the pith has disappeared below and for some distance above the amputation no new shoots are afterwards produced, though such will generally spring out when a stump of the branch is left. By pruning off a branch very close to even a young stem at the time of the completion of the midsummer growth no reproduction of shoots will follow, but instead of this a covering of bark is rapidly formed. But when pruning takes place between the time of the fall of the leaf in autumn and its full expansion in the spring numerous side shoots follow, and a slower growth of healing bark succeeds. As buds and branches do not grow without leaves, these are also proved to be essential to the production of pith. But the smaller radicles of the roots push forward even in the winter when the leaves are off, and hence it is assumed that these derive their nourishment from the reservoir of the pith. From observations of this kind it has been concluded that the uses of the pith are to act as a storehouse for the support of the buds, branches, and roots of trees in the early stages of their growth in the same way that the seed-leaves nourish the seedling plants. Just as the cotyledons dry up and fall away before the progress of the roots and the leaves, so the pith disappears in the wood as this approaches maturity.

The pith was called the medulla from its supposed resemblance to the spinal marrow of an animal; hence the layers round the central pith were called the medullary sheath, and the rays extending to the epidermis in the form of thin hard plates the medullary rays. These rays form the silver grain of the wood, and it is to their hardness and compactness that we owe the durability of cleft pales which are split up in the direction in which these run in the timber.

Flowers and flower buds.—The production of flower-buds is very similar to that of leaf-buds, except that in this instance there are within the leaves incipient flowers which are wrapped up in floral leaves called bracts. As soon as a flower-bud is formed it contains within itself the entire rudiments of the future flower. Flowers are the main organs of propagation, or reproduction. Their parts are commonly arranged in whorls, or rings, one within the other, and springing out of axils which are called bracts. These bracts sometimes form a kind of sheath for the flower, as in the lime-tree. Sometimes they form a cupule, or cup, as in the husk of the chestnut and the beech, and of the cup of the acorn. The foot-stalk is called a peduncle, and the internal arrangement of a flower is spoken of as its inflorescence.

The parts of a complete flower are shown in Fig. 9, which exhibits calyx (a. a.), corolla (b. b.), stamens (c. c.), and pistil (d.). Sometimes a flower has also a disc (e. e.).

The Calyx consists of a whorl of leaves named sepals. It forms the outer part of a flower, and is generally green in colour. It acts as a protection to the more delicate parts. The calyx is called regular or irregular according as its parts are of the same or of various sizes. The manner in which those parts are fitted together is spoken of as the æstivation. When they meet exactly by their edges they are valvate, and when they overlap each other they are imbricated.

The Corolla composes an inner whorl of leaves called the petals, each of which consists of a stem or unguis, and a broad part, which is called the limb. When these petals are distinct the flower is polypetalous, but when they form a kind of sheath or tube it is monopetalous. The petals of the corolla are generally bright in colours, forming the most attractive part of the flower. They are arranged alternately with the sepals of the calyx, and are either equal to or double the number of the latter. The floral envelope, as the calyx and corolla are sometimes called, acts as a protection to the organs of fertilization and fructification, which are hereafter described.

The Stamens are arranged round the inner portions of the corolla. They consist of two parts—the stalks, or filaments, and the heads, or anthers. The powder contained in the latter is called pollen. Generally the filaments are distinct, as is the case in the strawberry; but sometimes they grow together, as in the mallow, and then they are said to be monodelphous. When arranged in two parcels they are diadelphous, and when composed of more than two, polyadelphous. Occasionally the filaments spring from below the pistil, in which case they are left behind when the calyx is torn off; they are then said

to be hypogynous. Growing upon the sides of the calyx they are called perigynous. When upon the sides of the corolla they are called epipetalous, and when upon the top of the ovary they are epigynous. By means of the stamens the ovules become fertilized. The stamens are not always distinct, being sometimes found growing to one another. The pollen to the naked eye looks like a very fine dust, but in reality it consists of the most beautiful forms.

The Pistil occupies the centre of the flower, and it consists of one or more parts called carpels. The ovary is the lower portion which is hollow, tapering upwards into a thread called the style, and upon the top of which is the stigma. The inner space of the ovary is the placenta, and upon the sides of this the young seeds or ovules are formed. When the pistil ripens the fruit is formed, and the ovules become seeds. The seed, therefore, is only the full-grown ovule containing the embryo plant, which plant is seen to consist of three parts,—(1) The radicle, or young root; (2) the cotyledons, or young leaves; (3) the plumule, or young stem. When the embryo has two cotyledons it is called a dicotyledonous plant, and when only one, monocotyledonous. The ovary has within it a tissue or ridge properly called the placenta; and when this adheres to the walls of the ovary it is said to be parietal, but when it stands from the side and forms a central column with the seeds attached it is said to be free central. These details may appear minute, but they are of importance in the classification of plants and trees.

The Seeds.—The fruit is in botanical language only the seed vessel, which is sometimes in a hard dry covering called a shell, and sometimes in a fleshy covering, which is called the pericarp. Seed vessels, which open naturally to discharge their contents are said to be dehiscent, and indehiscent when they do not so open. Many of the seeds covered with shells are of a farinaceous kind; and among these may be reckoned the acorn, the beech-mast, the Spanish and horse-chestnut, the hazel-nut, the walnut, and the seeds of the hornbeam, maple, ash, plane, and sycamore. The birch, alder, and lime, though not strictly belonging to this class, are generally included in it. The farina contained in these seeds make them ill adapted for long keeping out of the ground, and at the same time it renders them liable to the attacks of rodents and birds when they are planted out early. Other seeds are hard and are contained in stones which are enclosed in pulpy fruit, as the cherry, mountain ash, whitebeam, holly, yew, and hawthorn. The cherry vegetates the same year it is sown, but the other seeds require pitting. Leguminous seeds are such as those of the common acacia, the robinia viscosa, and the

laburnum. These generally rise freely when sown direct from the trees. Light seeds are such as those of the poplar, willow, and some kinds of elm. They require to be carefully collected as soon as they ripen, otherwise they soon blow away. Resinous seeds are those of the pine and fir tribes. As they keep badly when separated from the cones, they are better left in these until nearly the time of sowing. In the majority of cases the cones are collected much too early in the winter and long before the seeds are matured.

Organs of Preservation.—Of these the bark, which has already been spoken of under the heading Epidermis, is the principal. It consists of annual cellular layers which detach from the vital membrane gradually extending the thickness of the bark. Sometimes the outer layer is thrown off, but it is generally persistent. As the inner portion of the tree swells the bark bursts longitudinally, giving to the trunk an indurated appearance. The astringent properties of the bark of many trees exercise highly preservative qualities, and also secure them from the attacks of insects. The hard shells of many seeds, the envelopes in which bulbs are enclosed, and the pulpy masses of tubes, apples, etc., are all preservative organs, some of which yield quickly to the action of the atmosphere or the soil in which they become embedded, while others protect the seeds uninjured for years.

Germination of Seeds.—After a seed is placed in the ground the radicle bursts through its covering and takes a downward course, sending out at right angles from its sides numerous rootlets. The cotyledons soon rise above the surface of the soil, and then expand with the plumule from which the leaves unfold. Directly after the expansion of the leaves the formation of the pith, and the connection between it and the buds, may be distinctly traced. The minute spongelets at the ends of the roots begin to take in food and to send it up to the leaves, where by the joint action of light, heat, and the atmosphere it is elaborated. As the result of separate trials it has been fully ascertained that germination takes places most freely in an atmosphere containing one part of oxygen to three parts of nitrogen—a condition which represents very nearly the composition of the air we breathe.

As germination cannot take place without heat, air, and moisture, so growth cannot proceed without light and soil. Fertile seeds contain not only the embryo of the new plant, but also carbon and nitrogen concentrated in the form of gluten and starch, which nourish the young plant in its infancy. The case protects it for some time from the effects of atmospheric influences; but when placed in the soil it soon absorbs moisture and distends. Air mixes with its nutriment

and prepares it for growth. The root is the first organ developed, and this pushes out uninjured through a weak point in the shell, towards which its growth is always directed. As soon as this is liberated it absorbs water and conveys it to the seed-leaves, which bring it under the influence of light. Immediately a great change takes place: from the gluten is produced a substance called diastase, which renders the starch soluble, when it instantly mixes with the sap, becoming sweet and changed into saccharine matter as it ascends, and afterwards into woody fibre as it protrudes through the soil and meets the light. By the time the internal store of food is exhausted, the plant is enabled to derive from the soil through its roots, and from the atmosphere through its leaves, its future supplies of nourishment.

Sustenance of Plants.—Vegetable extract, mucilage and carbon, with water as a vehicle, constitute the principal food of plants, presented to the roots under varying circumstances of soil and temperature which favour their assimilation, while atmospheric air, when of a suitable temperature and circulating freely amongst the trees, acts upon them through the leaves and the bark. The effects of stagnant air may be seen in cases where from want of a proper circulation and the exclusion of light the side branches die and drop off, leaving only a few green ones at the top, the tree increasing principally in length as these push up in quest of food.

Some writers have assigned to plants the power of selecting their food from the solids in the soil without the aid of water, while the opinions that water alone and even air alone are sufficient to secure plant growth have also been advanced. Pure water can only be obtained by distillation, as it does not exist in nature unmixed with gaseous, saline, or earthy matters. These matters are carried into the leaves and the bark along with the water which is thence evaporated, leaving the substance behind. Whatever enters the plant, whether in the form of carbonic acid or as water and atmospheric air, becomes decomposed, after which some of its elements pass off, while others recombine in different proportions, forming gum, sugar, fecula, and azotic products.

A plant whose roots are placed in pure water will not flourish until carbonic acid is admitted. Carbon, of which the substance of plants so largely consists, can only enter the plant as carbonic acid gas, as may be proved by placing the roots in pounded carbon, and watering with distilled water, when no growth will take place. Nitrogen, or azote, contributes largely to the nutrition of plants, and its presence in the gluten and the vegetable albumen, as well as in the alkalies, shows that it is essential.

Silex is taken up by some plants in large quantities, and more especially by the grasses and the bamboo. It is stated that the skin, or covering, of the rattan palm contains so much of it that sparks are produced by striking this tree with a piece of steel. It is well known that silex is present in considerable quantities in the teak-tree, and also in the equiseta, or horse-tails.

Lime and the salts of lime—the sulphate and phosphate,—magnesia, sulphur, soda, potash, phosphorus, and metallic substances, are found in plants, soda being generally the most abundant. Even copper is found in the coffee-berry. The quantity of water passing through any plant which presents to the sun and the atmosphere a large evaporating surface may be inferred from the experiments of Hales, who ascertained that a sunflower only three feet high lost twenty ounces of water daily.

The way in which the points of the roots push forward into fresh soil as the old becomes exhausted of its nourishment, or turn aside and spread out in other directions when they meet with any impediment to their onward progress, even passing through small crevices and bursting asunder the stones by their powers of expansion, furnishes us with an instance of the wonderful provision made by nature for the supply of the wants of the vegetable creation.

A perfect knowledge of the composition of plant-food would enable us to fertilize any soil which did not contain ingredients positively poisonous to plants. Root structures show that whatever enters them must be in a very minute state of subdivision; and chemistry proves that this comprises sulphates of lime and potash, vegetable extract, muriates of lime and soda, or common salt, and that, unless oxygen be present, both in the soil and the air by which they are surrounded, plants cannot vegetate.

In the February number (1880) of the *Journal of Forestry* is a short review of a valuable little pamphlet lately published at the request of the Scottish Horticultural Association, and written by Mr. W. Ivison Macadam, of Edinburgh. But as is usual in such publications, the illustrations of the composition of plants are confined to farm crops. The sooner the services of such an analyst can be enlisted in the cause of arboriculture the better for students of the science. As Mr. Macadam gives important information upon various points which have already been treated of more discursively in his work, a summary of his tables of plant-food will supply me with an appropriate recapitulation.

The principal mineral ingredients in plants are nine in number: potash, soda, lime, magnesia, iron, phosphoric, sulphuric, and silicic acids and chlorine.

Potash, containing the metal potassium (K), also present in nitre or saltpetre (KNO_3), in muriate of potassium, or chloride of potassium (KCl), and in kainit as sulphate along with the chloride of magnesium.

Soda, containing the metal sodium (Na), which also forms a part of common salt or chloride of sodium (NaCl), Glauber's salts or sulphate of soda (Na_2SO_4), and nitrate of soda or cubical nitre ($NaNO_3$).

Lime, a compound of calcium (Ca), also existing in chalk or carbonate of lime ($CaCO_3$), and stucco, gypsum, or sulphate of lime ($CaSO_4$), and in bone in combination with phosphoric acid as insoluble or bone phosphate (Ca_32PO_4).

Magnesia, containing magnesium (Mg), also found in Epsom salts, or sulphate of magnesium ($MgSO_4$), and as chloride of magnesium ($MgCl_2$) in kainit.

Oxide of iron, consisting of iron and oxygen.

Phosphoric Acid (PO_5). Its principal state of combination is with lime as bone phosphate (Ca_32PO_4), and as soluble phosphate ($Ca2PO_3$).

Sulphuric Acid (SO_3), found in combination with lime as stucco ($CaSO_4$), and forming the acid portion of Glauber's salts (Na_2SO_4).

Silica is made up of silicon and oxygen. It forms sands, and in combination with metals silicates.

Chlorine is a yellow-green gas, and is found as a part of common salt (NaCl), muriate of potash (KCl), and chloride of magnesium ($MgCl_2$).

The organic constituents of plants are starch, sugar, dextrose, oil, gluten, legumin, cellulin, and lignin.

Starch ($C_6H_{10}O_5$) softens in cold water and gives a semi-solution in hot.

Sugar ($C_{12}H_{22}O_{11}$) is found principally in the stems of plants, chiefly grasses, as the sugar-cane; and a few trees, as the maple and date palm; and also in the tubers of beet and carrots.

Dextrose, or grape sugar ($C_6H_{12}O_6$), is another variety of sugar principally obtained from fruits. *Oil* is obtained from rape seed, the castor plant, and the cocoa-nut. *Gluten* is a white sticky substance obtained by washing flour in a cloth with water. It is abundant in cereals. *Legumin* is obtained from peas, beans, tares, &c. *Cellulin* composes the walls of the cells in plants. *Lignin* is a hard matter or woody fibre deposited in the cells.

The Classification of Plants.—The necessity for a systematic classification will be obvious when we consider that there are already included in the catalogue of the botanist more than 150,000 species of plants, and that the floras of many regions in America, Africa, Australia, India, and China are still very imperfectly known.

The natural divisions of plants are Herbaceous, Shrubs, and Trees. *Herbaceous* plants have succulent, juicy stems, and they are either annuals, biennials, or perennials. These are either multiplied by dividing the roots, by means of offsets, by cuttings taken from the side shoots, or by seeds. The stems of herbaceous plants consist chiefly of cellular tissue, and these for the most part die down to the ground annually.

Shrubs are ligneous or woody-stemmed plants which have generally several parts of nearly the same thickness springing from one root. Their period of life is not often more than from 40 to 50 years.

Trees, properly so called, are single-stemmed as they rise from the soil, though many of them fork out immediately afterwards. When these are exogens (of which more hereafter), their ages are generally calculated pretty accurately by the number of concentric rings which exist between the pith and the bark. But this method of computation, though sufficient for ordinary purposes, is by no means infallible. In a warm, early spring the sap is soon set in motion, and if cold weather follows vegetation becomes checked, though it afterwards gets a second start, in consequence of which the appearance of the trunk at the end of that season will indicate two years' growth. Sometimes a second growth commences at midsummer; and this is very frequently the case with the oak and the elm; so that it is possible for even a third layer to be formed in the same year. Again, during a warm or a very mild and moist winter the growth of the tree occasionally receives no check, so that the increase of two years may form only one ring upon the trunk.

The length of life of any tree depends very much upon soil and situation. When the natives of mountainous regions are planted in sheltered spots and upon a rich soil they grow rapidly, and are sooner exhausted. The timber also is of less value on account of its imperfect lignification. But when the native of a lower region is placed upon a more elevated site and in a poorer soil, if it survives at all the period of its existence is lengthened, and its trunk, though smaller in size, produces tough and durable timber, as in the case of the Highland Oak.

Various methods of classification have been adopted by botanists, some of which are called artificial, and others natural systems. *Artificial Systems* have had their chief expounder in Linnæus, whose method is founded on the essential organs of reproduction in plants. With him plants are divided into flowering and flowerless: the former, called also *Phanerogamia*, he arranges in twenty-three classes, whose characters are determined by the number, position,

and the length and connection of the stamens: the latter, called *Cryptogamia*, he arranges under twenty-four classes, which approach more nearly the divisions under the natural system. The first comprehensive *Natural System* was that of Ray in 1682. He also separated flowering and flowerless plants, and arranged the former under the two heads of Dicotyledons and Monocotyledons. Thus he laid the foundation of the system which has been still further elucidated by the labours of Jussieu, De Candolle, and Lindley.

The arrangement of plants according to the natural system is one which requires a fair knowledge of structural botany, and also some acquaintance with the theoretical part, called morphology. The elementary tissues are divided into cellular and vascular, the one composing the lower tribes of flowerless plants and the other the higher. Among the organs of nutrition the highest place is assigned to the embryo. By an examination of this we are enabled to divide plants into Acotyledonous, Monocotyledonous, and Dicotyledonous. Upon an examination of the secondary organs of nutrition we find the stems of cellular or thallogenous plants are veinless; the fronds of acrogens have a forked venation; endogens have parallel-veined leaves, while those of exogens are reticulated.

The usual divisions of plants consist of classes, orders, genera, and species, and these are again subdivided,—the first into sub-classes, the second into tribes and sub-tribes, the third into sub-genera, and the fourth into varieties.

A *species* has been described as an assemblage of individuals presenting certain constant characters in common and derived from one individual stock. What are called varieties are simply alterations in species, and though careful cultivation ensures to a certain extent the permanence of these, through neglect they often revert to their original stock.

Genera are species nearly related, as the dog-rose, the Scotch rose, the China rose, and the sweetbriar, all of which produce a fruit called the hip. The oak also includes nearly 200 species distinguished by the acorn.

Orders are groups of genera which bear a strong family likeness; thus pines, larches, and firs, being different genera, but all producing cones, are classed under the order Coniferæ. The oak, the hazel, the beech, and the chestnut are all arranged under the order Cupuliferæ, on account of their producing the cupule of the acorn, which is also known by the name of husk in the filbert, chestnut, and beech-mast.

Classes are collections of orders which agree in all important characters, such characters being permanent, and therefore called essential.

By the natural system of De Candolle, plants are arranged under three principal heads:—Exogens, Endogens, and Acrogens. In the two former the organs of reproduction are obvious, hence these flowering plants are called Phanerogamous, from the Greek word *phaneros*, which means conspicuous. In the last the organs are obscure, hence they are called flowerless or Cryptogamous, from *kryptos*, which means concealed.

Exogens have their woody and cellular systems separated, the former being arranged round the pith in zones of a concentric form. All plants belonging to this class have branch-veined leaves. Their stems have a central pith, a ring of wood, and a covering of bark. The lines radiating from the pith to the bark are called medullary rays. In this class of plants the embryo of the seed is dicotyledonous. The stems thicken as they grow older, and consequently both trunks and branches are more or less conical. The numbers of the parts in their flowers are generally indicated by powers of 4 or 5. The European Flora consists mainly of Exogens, and, indeed, nearly all plants growing here in a wild state belong to this class.

In Fig. 11, A shows a horizontal and B a vertical section of the trunk of an Exogen. The central pith extends from the roots through the trunk to the

FIG. 11.

ends of the branches. This is generally solid, but in umbelliferous plants it adheres to the inside of the rapidly-expanding cylinder, so that an empty tube is produced. The medullary rays or processes, by means of small points or slits, radiate from the pith outwards. These processes cut up a section of the wood into a number of wedge-shaped pieces, the broadest parts of which are next the bark of the tree. The office of these rays is to enable the descending sap to reach the inner portion or heart of the tree. An illustration of these

processes and of the way in which they communicate with the pith is given in Fig. 12.

Exogens, or outward growers, are divided into four sub-classes.

1. *Thalamiflorœ*, in which the flowers are furnished with both a calyx and a corolla, the latter consisting of distinct petals. Upon these the stamens are hypogynous, that is, they are united to the sides of the ovary.

2. *Calyciflorœ*, which generally have both calyx and corolla, the petals of

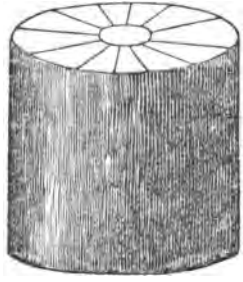


FIG. 12.

the latter being distinct. In these the stamens are perigynous, or arranged round the ovary, or epigynous, that is, arranged upon the ovary. This sub-class is commonly divided into Polypetalæ, having separate petals, and Monopetalæ, with united hypogynous petals.

3. *Corolliflorœ*, having flowers furnished with both calyx and corolla, the latter consisting of united petals.

4. *Monochlamydæ*, whose flowers have no corolla, and oftentimes no calyx. These are called apetalous.

Endogens, or inward growers, have parallel-veined leaves, the veins either passing from one end of the leaf to the other, and parallel with the midrib, or diverging towards the margin, when they are called curve-veined. Where the veins continue their branchings with ramifications getting smaller and smaller, and gradually growing into one another, the leaves are called reticulated or netted-veined. The stems of endogens are confused masses of pithy matter, in which there is little or no distinction of parts, the pith, the fibre, and the bark or outer covering all blending. Sections of this kind are shown in Fig. 13.

Such stems do not thicken much, but they elongate with age. Their form is more cylindrical than conical, and internally they become more woody as they get older. The parts of their flowers are commonly some power of 3. Endogens are so named because the woody matter is formed upon the interior of the trunk. Theophrastus speaks of this difference in writing of the palm tree ("Hist.," i. 8). The woody bundles of which the trunks consist are developed from the interior to the exterior. Endogens as a class are tolerably

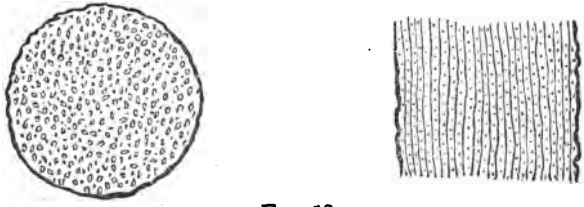


FIG. 13.

uniform in structure. The common cane and the asparagus afford typical illustrations of their modes of growth.

This class of trees has spiral vessels, stomata, generally a parallel venation, and flowers with stamens and pistils. It is sub-divided into—

1. *Petaloidæ*, all of which have parallel-veined leaves;
   (*a*) *Epigynæ*, having flowers with stamens and pistils, and an inferior ovary;
   (*b*) *Hypogynæ*, with stamens and pistils, and a superior ovary;
   (*c*) *Incompletæ*, having incomplete flowers, with no proper perianth, or with verticillate scales.
2. *Glumiferæ*, which have a parallel venation, and whose flowers consist of imbricated bracts or glumes.

Acrogens, or summit-growers, are flowerless plants which multiply by means of spores. They do not increase in diameter, but elongate with age. Acrogens are divided into two classes, the Acrogens proper, which have a distinct stem, with branches and leaves, and Thallogens which have no distinct stem, but only a cellular expansion or thallus. The higher orders have stomata. Generally speaking these are plants of small stature, but in ferns they sometimes attain the height of trees, having a simple stem. Whenever they branch naturally they do this in a forked manner. The common equisetæ, or

horse-tail, is a well-known type of these plants. In the tree-ferns of New Zealand and Van Diemen's Land their stems rise to a height of 40 or 50 feet. Their growth is accomplished by the petioles of the leaves being joined together, and consequently the wood resembles neither the concentric circles of the exogen nor the fibrous substance of the endogen, but a succession of zigzag layers, derived from the footstalks of decayed leaves of a large size.

In Fig. 14, A represents the scars of the leaves upon the outside of the trunk, and B the transverse section of the stem, with its bundles of vessels at (*a*)

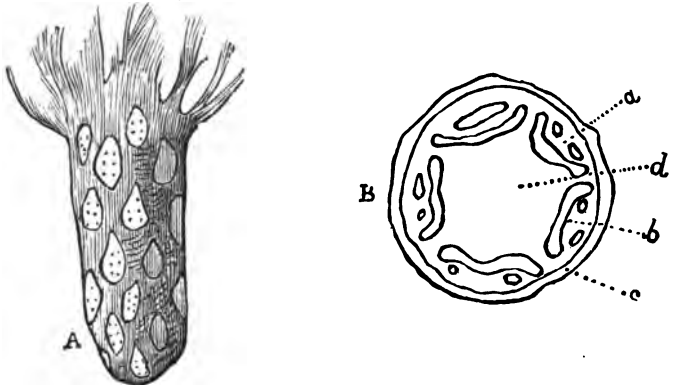


FIG. 14.

and (*b*), irregular in form, dark outside and pale within; (*c*), outer layers of cellular tissue, and (*d*), central cells, in the place of which there is sometimes a cavity.

Within the limits of these pages it is impossible to enter upon a description of the various orders under which plants and trees are arranged. These the student will find systematically classified in any one of the numerous treatises upon botany which have appeared of late years, and in none more clearly than in the "School Botany" of Dr. Lindley and the elementary works of Professor Balfour. The following classification of an important order of forest trees will give some idea of the manner in which the subject is treated by the former.

ORDER.—SALICACEÆ.

The downy seeds of willows and poplars growing at the bases of leathery two-valved capsules, give such plants a mark of recognition which cannot be mistaken. The most northern woody plants known are the willows called *Salix artica* and *S. polaris*. This order is valuable both for its timber and for economical purposes. The bark is astringent, tonic, and stomachic. That of *Populus tremuloides* in the United States and of *P. tremula* and *P. alba* in Europe is known as a febrifuge. Salicine, a substance used to arrest the progress of fever, has been prepared from *S. fragilis, pentandra, Russelliana, vitellina*, and *purpurea* in Europe, and from *eriocephala, nigra*, and *conifera* in the United States. The buds of *S. nigra, balsamifera*, and *candicans* are used in compounding an ointment, for tumours, wounds, and burns. Osiers generally are useful in wickerwork, and the wood of the sallow makes good charcoal. *S. alba* is found serviceable for cricket bats, and the aspen for arrows. Some of the poplars are also used for turnery, for flooring boards, for wheeling planks, and for wheelbarrows for rough work.

Flowers unisexual. Stamens distinct or monodelphous. Ovary superior, one or two-celled, ovules numerous, style 1 or 0, stigmas 2. Fruit coriaceous, one or two-celled, two-valved, many-seeded. Leaves alternate and simple. Stipules deciduous or persistent. Trees or Shrubs.

I. **Salix.**—Flowers dicœcious, seldom monœcious. Catkins consisting of imbricated bracts. Stamens from 2 to 5. Fruit a one-celled follicle. Seeds comose.

(1) *S. caprea* (Sallow). Leaves roundish ovate, serrated, waved, pale and downy beneath. Catkins oval. Fruit swelling. A small tree.

(2) *S. fragilis*. Leaves ovate-lanceolate, pointed, serrated throughout, very smooth. Ovary ovate. Stigmas cloven, and longer than the style.

(3) *S. Russelliana* (Bedford Willow). Leaves lanceolate, tapering at each end, serrated throughout, very smooth. Ovary tapering and stalked. Woods. A tree.

(4) *S. purpurea*. Branches trailing, decumbent. Leaves partly opposite, obovate-lanceolate, serrated, very smooth, narrow at the base. Stamen 1. Woods. A small shrub.

(5) *S. vitellina*. Leaves lanceolate, acute, smooth above and somewhat silky and glaucous beneath. Stipules minute, lanceolate, deciduous, and smooth. Osier grounds. A tree.

(6) *S. alba.* Leaves elliptic-lanceolate, pointed, serrated, silky on both sides. Stamens hairy. Woods. A large tree.

II. **Populus.**—Dicœcious. Catkins cylindrical, with lacerated bracts. Stamens from 8 to 30. Seeds comose.

(1) *P. nigra* (Black Poplar). Leaves deltoid, pointed, serrated, and smooth on both sides. Catkins all lax and cylindrical. Stigmas 4, simple spreading. Woods.

(2) *P. alba* (the Abele Poplar). Leaves lobed and toothed, somewhat heart-shaped at the base, snow-white and downy beneath.

(3) *P. canescens* (the White Poplar). Leaves roundish, deeply waved, toothed, hoary and downy beneath. Stigmas 8. Woods.

(4) *P. fastigiata* (the Lombardy Poplar), branches very erect, forming a long cylindrical head. Leaves deltoid, unequally serrated, smooth. Plantations.

(5) *P. tremula* (the Aspen Tree). Leaves nearly orbicular, toothed, smooth on both sides. Footstalks compressed. Young branches hairy. Stigmas 4, erect. Woods.

The Distribution of Plants.—The plant life of any particular country or district is called its *Flora*, just as its animal life is known by the name of its *Fauna*. Between the two classes there is everywhere a certain inter-dependence, the herbivorous animals subsisting on plants, while the carnivorous prey upon the plant-feeders. In consequence of this it is found that wherever vegetable life is luxuriant and at the same time considerably varied, animal life is also abundant.

As plants are mainly dependent upon heat, light, and moisture, all of which they obtain in the greatest intensity near the equator, the most exuberant vegetation is found within the tropics, and it gradually decreases towards the polar regions. Other things considered, life is also found to be more dense near the sea-level, becoming rarer as we either rise above or descend below this line.

The natural habitat of a plant is that in which it finds all the elements which contribute to its vigorous growth and to its perfect form and development. In speaking of the range of habitat we generally understand the geographical range, which is circumscribed by temperature, light, and heat, and by elevation. Thus in the prosecution of his researches the botanist finds that vegetation radiates from certain centres. It is also seen that the wild luxuriance of tropical jungle-growth is as much owing to excessive heat and abundant

moisture as the barrenness of Nova Zembla is due to intense cold. The final distribution of plants is in some degree due to the action of man, to birds, winds, rivers, and tides.

Some idea of the natural distribution is obtained from their arrangement under the heads of aquatic, aërial, and terrestrial. *Marine* plants grow in salt water and float upon its surface, as in the case of seaweed; *maritime* plants grow upon the seashore or within the influence of the sea-breeze; *aquatic* is a name applied generally to fresh-water plants, which may be either lacustrine, fluviatile, or palustrine.

Trees and plants of various kinds may be to a great extent acclimatized, though such change of location is often attended by an entire change of habit; thus the potato, which is a native of tropical America, is found to flourish and become eminently useful in northern Europe. But while in its own country the tubers are small and its propagation is carried on by means of the seed; here the former are large and contain a store of nutriment sufficient for the young plant. Any important change of character such as the above is reversed as soon as plants are restored to their own proper places. Sometimes it is found difficult and even impossible thus to acclimatize plants, and many of those which flourish under the influence of the sea-breeze languish or perish altogether when removed inland.

Climate may be considered as the main element in the regulation of the distribution of trees. This in general depends upon the distance of any place from the equator. Within the tropics the length of day and night is nearly equal, and the seasons are known as the wet and the dry, the latter being considered as the summer and the former the winter. But in the West Indies and in some other inter-tropical countries there are two rainy and also two dry seasons in the year. As we approach the temperate zones, the regular succession of seasons—spring, summer, autumn, and winter—commences, and these prevail between the parallels of 35° and 60.° Again, the frigid zone has only two seasons—a long, severe, and partially sunless winter, and a brief summer of continuous sunlight. The above characteristics are descriptive of the general climate in so far as this is dependent upon latitude. But climate is subject to great modifications from *altitude*, which in its turn is influenced by winds, by aspect, or the slope of the land, and by the proximity of the sea. In temperate zones every ascent of from 300 to 350 feet lessens the heat by one degree; and at greater heights and in still higher latitudes the ratio of decrease is even more rapid.

What are known as *insular climates* are such as from the proximity of the sea are cooler in summer and warmer in winter than other inland regions which have similar latitudes and like elevations. Thus the climates of Great Britain, of Tasmania, and of New Zealand, are insular. Such climates as those of the centre of Russia, Germany, and Tartary, are called *continental* ones. Humboldt observes that in the northern hemisphere the continents and large islands are warmest upon their western sides, and in the southern hemisphere upon their eastern.

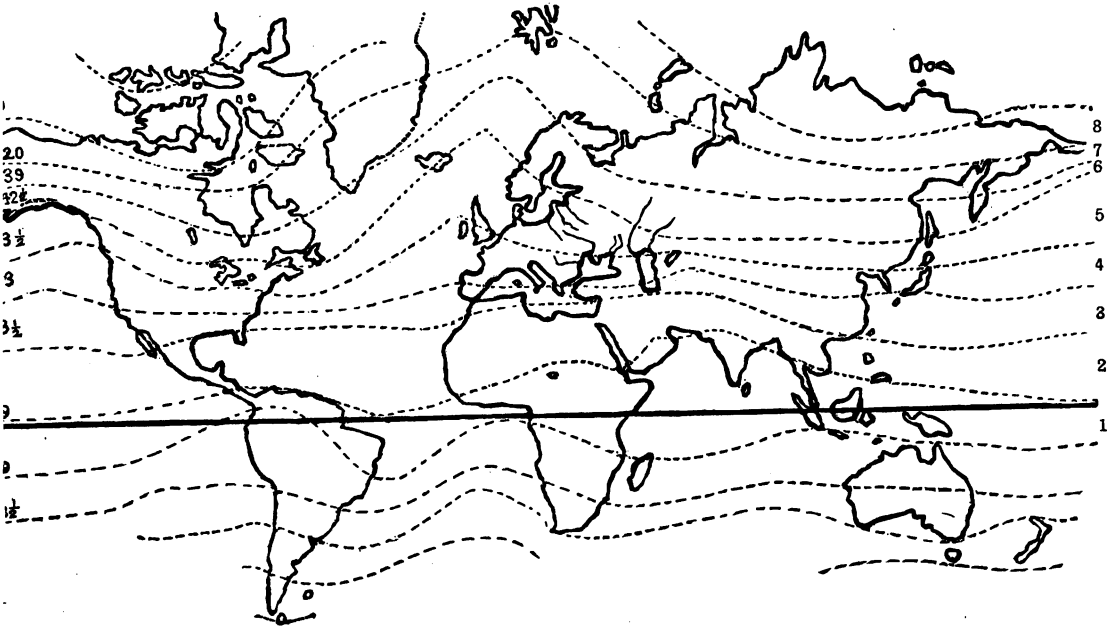
A great influence upon both the climate and the humidity of a region is exercised by the direction of its chains of mountains, accordingly as these keep out the cold winds or intercept the dry ones. Cultivation has also a marked effect upon climate, which is considerably influenced by the presence of timber and by drainage.

The climate of any country is spoken of either as *geographical*—dependent upon latitude; or *physical*, which depends more upon the situation and aspect. The distribution of species mainly follows the first of these, and the quality and growth of timber the second. The extensive growth of timber in any district tends to minimise changes, as the temperature in summer is lowered by the shade of the trees, while the checking of terrestrial radiation in winter considerably decreases the cold. Forests also break the force of the winds and give a more humid atmosphere.

Any one country may present great varieties of climate which are characterised by as many distinct growths of trees. In France 330 feet of elevation reduces the heat equivalent to one degree of latitude; and Professor Bagneris, who has devoted great attention to the timber growths of that country, divides it into the following districts:—1. Hot climate, producing oaks (*Quercus suber*, *ilex*, and *coccifera*) and pines (*Pinus halepensis* and *pinea*); 2. Mild climate, growing *P. pinaster* and *Q. sessiliflora* and *pedunculata*; 3. Temperate, growing oak, hornbeam, and beech; 4. Cold, producing beech and silver and Scotch firs; 5. Very cold, growing the sorbus, pyrus, betula, and the spruce fir, larch, and some pines.

Even in a country possessing so little variation in height as Britain the different elevations exercise a very marked effect upon the growth of trees—the pine, fir, and birch being found upon the highest ground, next the sycamore and mountain elm, and then the oak, beech, poplar, ash, and chestnut. It is by some approximation to this natural planting, which is sometimes called region planting, that we may hope to attain the greatest success.

ISOTHERMS AND ZONES OF VEGETATION.



REGION OF

1. Palms and Evergreen Forests.
2. Tree Ferns, Sugar Canes, &c.
3. Evergreens and Vines.
4. Large Forest Trees.
5. Coniferous and Deciduous.
6. Shrubs.
7. Grasses.
8. Lichens and Mosses.

Soil also has a marked influence upon the distribution of plants; but upon this point so much has been said in previous pages that it is unnecessary to revert to the subject.

In order to indicate the regions of equal temperature a system of marking out the maps by means of isotheral lines (so called from *isos*, equal, and *theros*, summer) has been adopted, and these are so drawn as to pass through places the temperatures of which are equal. It is customary to mark these upon the maps at distances of 10° north or south latitude. By this method the surface of the earth is mapped out into a succession of zones of vegetation which are bounded by isothermal lines, which indicate the mean amount of heat received throughout the year. These zones may be described as follows. (See Diagram).

1. *The Equatorial Zone*, bounded by the isotherm of 79°. Here, wherever the moisture is abundant, growth is luxuriant. The stems are generally succulent, the flowers very large and showy, the climbing plants or parasites of immense size. The grassy kinds develop into bamboos and canes, and large orchids and palms abound. Most of the vegetable growth of this zone lies to the north of the equator. It may be described as covered with very dense evergreen forests.

2. *The Tropical Zone*, extending to the isotherm of 73½° on both sides of the equator, and abounding in palms, tree-ferns, cotton, coffee, and sugar-cane, as well as bananas. Here the climbing plants decrease, and underwood becomes more abundant.

3. *The sub-Tropical Zone*, bounded by the isotherm of 63°. This belt is rich in magnolias, myrtles, laurels, figs, palms, cacti, vines, and arborescent euphorbias. The vegetation is for the most part evergreen. The climate of this zone is splendid, but in some places it is rainless.

4. *The higher Temperate Zone*, called also the warmer temperate, and limited by the line of 53½°. There is still an abundance of evergreen trees, but few or no palms. Here are fine forests of deciduous trees,—oaks and chestnuts, olives, pomegranates, figs, oranges, and the vine. These abound chiefly in the zone of the northern hemisphere, while in the southern we meet with araucarias, some ferns, and aborescent grasses.

5. *The lower or colder Temperate Zone*, extending to 42½°. This in the northern hemisphere is the principal zone of forest trees, and in consequence of most of these being deciduous we here experience marked seasonal contrasts. The growths of England and the more northern parts of France and Germany

are typical of this region, producing fir, pine, yew and coniferous trees generally, interspersed with large expanses of heath. This zone is almost the northern limit of the profitable cultivation of wheat.

6. *The sub-Arctic Zone,* limited by the isotherm of 39°, and producing pine, larch, spruce, juniper, beech, poplar, heaths and grasses, and in its extreme northern limits birch, alder, and willow.

7. *The Arctic Zone,* which is confined to the northern hemisphere, growing a few pines and firs, together with the dwarf birch, the alder, the willow, some grasses, and gradually giving way to lichens and mosses. In America this zone produces the rhododendron and the azalea.

8. *The Polar Zone,* also confined to the northern hemisphere, and producing only flowerless plants, such as lichens and mosses. Sometimes during its short summer the ranunculus, the rush, and a very dwarf willow spring up, but generally speaking this zone is destitute of all trees and bushes.

The ascent of a lofty mountain displays the successive zones of vegetation much in the same way perpendicularly as we should pass through them horizontally in going from the equator to the north pole; and as far as temperature is concerned we should pass through a corresponding series of climates. In a country which contains every difference of level, the various productions of those different altitudes may be brought together in one common market. Thus it happens that the markets of towns in equatorial regions are frequently supplied with produce which appears to have been collected from extreme points of the earth's surface. At the market of Bogota, in South America, may be seen on one side hampers of strawberries, apples, and peaches, and close to these piles of pine apples; heaps of cabbages, carrots, and potatoes, alongside yuccas and bananas; piles of cocoa and sugar, between sacks of maize, barley, and wheat; medicinal herbs gathered in the mountains by the Indians, and arranged near these pinks, roses, and jessamines.

In commencing observations at any particular latitude we should find the vegetation beginning with the flora of that parallel and gradually ascending through succeeding zones. Thus if we take the Pyrenees, and commence at the sea-level, we find: 1. A zone of oaks; 2. Beech trees; 3. Silver fir and yew trees; 4. The Scotch pine; 5. Dry-leaved shrubs and creeping plants, such as the rhododendron, daphne, and dwarf willow; 6. Alpine plants, gentians, primroses, etc.; 7. The latter together with mosses and lichens, extending to the limits of perpetual snow.

If we take a higher latitude, such, for instance, as the head of the Gulf of

Bothnia, we find: 1. Spruce fir; 2. Scotch fir; 3. Dwarf birch trees, thick and knotty; 4. *Betula nana*, another kind of dwarf birch, and a green willow; 5. Woolly willow and a creeping small birch; 6. Amongst patches of snow a few dwarf shrubby plants. 7. Saxifrage and crowfoot wherever the soil is visible; 8. Amongst perpetual snow if a portion of the soil becomes exposed only for a few days, the icy crowfoot flowers.

The South American flora begins with bananas, cycads and palms at the level of the ocean; next upon the valleys of the Andes, tree-ferns and cinchonas, or Peruvian bark trees; then ivies and andromedas and heaths; then the resin-yielding bejarias, which form a purple belt round the mountains. Upon reaching the Paramos stony region lofty plants and flowering herbs disappear, and are succeeded by large tracts of grasses upon which the llama feeds. We next meet with lichens and thalli, and then reach the limits of perpetual snow.

Humboldt tells us: "We may begin the ascent of the Alps in the midst of warm vineyards, and pass through a succession of oaks, sweet chestnuts and beeches, till we gain the elevation of the more hardy pines and stunted birches, and tread on pastures fringed by borders of perpetual snow. At the height of 1,950 feet the vine disappears; and at 1,000 feet higher the sweet chestnuts cease to thrive; 1,000 feet farther, and the oak is unable to maintain itself; the birch ceases to grow at an elevation of 4,680 feet, and the spruce fir at the height of 5,900 feet, beyond which no tree appears. The rhododendron then covers immense tracts to the height of 7,800 feet; and the herbaceous willow creeps 200 or 300 feet higher, accompanied by a few saxifrages, gentians and grasses; while lichens and mosses struggle up to the barrier of eternal snow."

Plants and trees sometimes abound in tribes, and as such give distinctive features to the countries in which they prevail; thus the tea plant and camellia belong to Eastern Asia, eucalypti to Australia, magnolia to the southern latitudes of North America. Such effects are also produced by the palm, the banana, cactus, willow, and by grasses and heaths.

A tract of country or a district to which certain orders are peculiar, constitutes a botanical region; thus we have regions of magnolias, palms, etc. The natural range of some of these is limited, but on account of their utility or their ornamental appearance, they are transferred from one region to another, sometimes to the partial destruction of the vegetation amongst which they are introduced, and with which they become acclimatized. But generally speaking Nature's law prevails, and oftentimes the vigour which such trees displayed in their native habitat is lost. Thus the winters of some years have